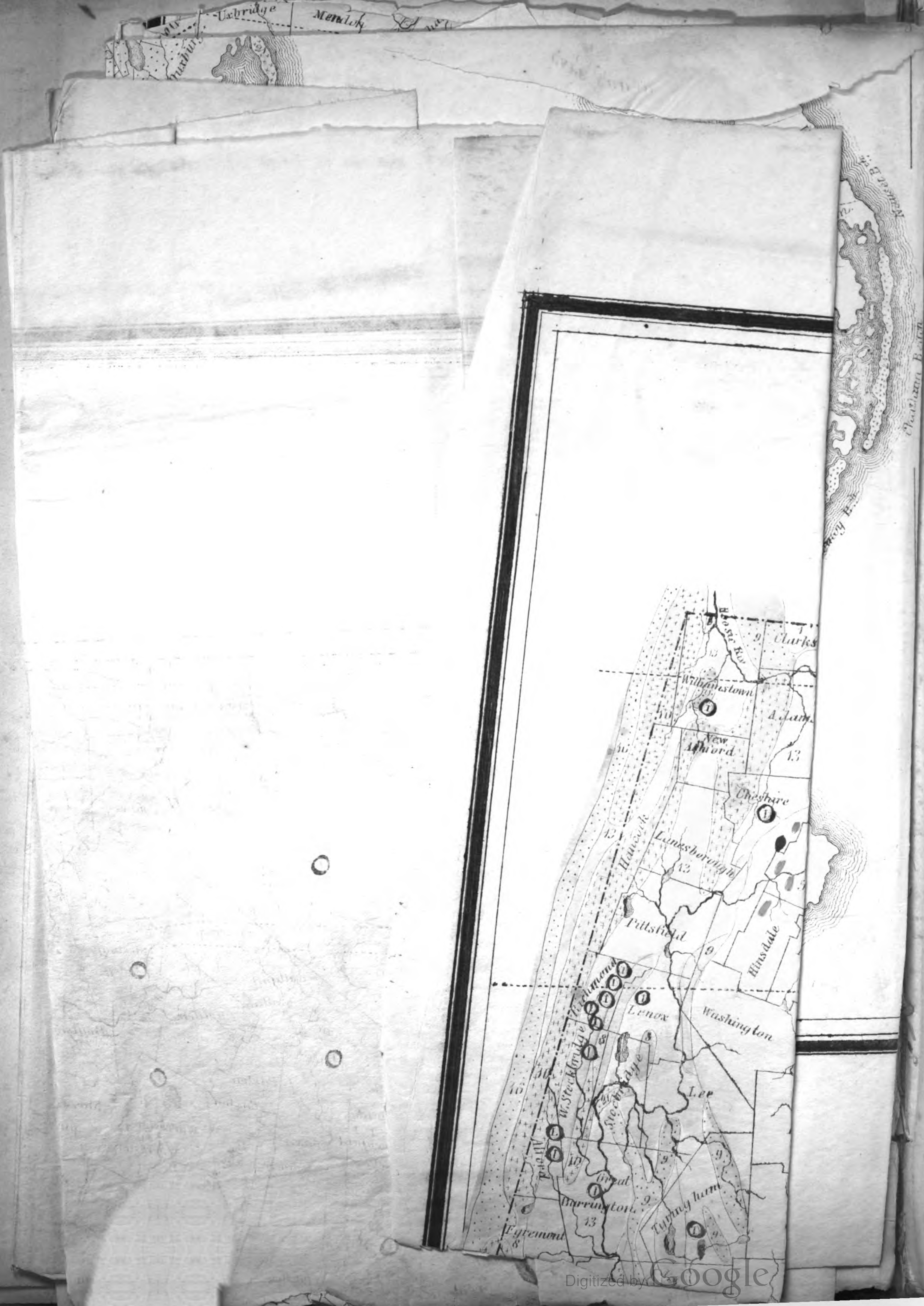
Uxbridge
Mendon
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Richmond
Lenox
Washington
W. Stockbridge
Stockbridge
Lee
Alford
Great Barrington
Egremont
Tyringham

# FINAL REPORT

ON THE

# GEOLOGY OF MASSACHUSETTS:

In Four Parts:

I. ECONOMICAL GEOLOGY.
II. SCENOGRAPHICAL GEOLOGY.
III. SCIENTIFIC GEOLOGY.
IV. ELEMENTARY GEOLOGY.

WITH AN APPENDED CATALOGUE OF THE SPECIMENS OF ROCKS AND MINERALS IN THE STATE COLLECTION.

BY EDWARD HITCHCOCK, LL. D.

PROFESSOR OF CHEMISTRY AND NATURAL HISTORY IN AMHERST COLLEGE: GEOLOGIST TO THE STATE OF MASSACHUSETTS, ETC.

AMHERST: J. S. & C. ADAMS.
NORTHAMPTON: J. H. BUTLER.
1841.

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## To His Excellency Edward Everett,
## Governor of Massachusetts:

Sir,

I am happy to be able at length to present you with my final Report on the Geology of Massachusetts. I have divided it into four Parts:

1. ECONOMICAL GEOLOGY:
2. SCENOGRAPHICAL GEOLOGY:
3. SCIENTIFIC GEOLOGY:
4. ELEMENTARY GEOLOGY.

The *Economical Geology* contains a description of all the minerals and rocks in the State hitherto discovered, that have been applied to useful purposes. To this part of the subject I have devoted more attention since my re-appointment as State Geologist, than to any other. The difficult yet important subject of soils; their chemical composition, geological character, and means of improvement, were scarcely alluded to in my former general report; but in the present one, it occupies a conspicuous place. By the liberal assistance of a distinguished chemical friend, I have brought forward on this subject many new views, which I trust will prove valuable. In applying these views, numerous analyses have been requisite. I have performed many others, also, upon other substances, to ascertain their value: so that the whole number which I have given, amounts to about 400. In fact, my former reports exhibit but a meagre account of our economical geology, compared with the present; however imperfect even this may be.

The *Scenographical Geology* embraces a description of the most remarkable natural scenery of the State, accompanied by drawings of the most interesting spots. These drawings I have succeeded in obtaining through the liberality of several artists, who have gratuitously accompanied me in my tours; and though they should be engraved in plain style, they may aid in calling the attention of our citizens to striking features in our scenery, that are now generally passed unnoticed. This is the chief object of this part of my Report: and if I succeed in it, I shall feel as if an important point were gained.

The *Scientific Geology* considers the bearings of the subject upon the principles of the science, without direct reference to practical utility: although the theoretical principles of this science have an important relation to practical utility. On this part of the subject a great number of new and curious facts have come to my knowledge since the publication of my former Reports. I have spent a great deal of time also, in tracing out more accurately the boundaries of the different rock formations upon the accompanying corrected geological map. I have also added to the State Collection of rocks, minerals, and soils, 1303 specimens; so that the whole number now amounts to 2857.

Under *Elementary Geology*, I have given a condensed view of the terms, principles and theories of the science of geology in general. I have done this in the hope of aiding those persons who may wish to read this Report, who have not the leisure or the means of consulting the larger works that have been published on the subject. My chief fear is, that I have been obliged, for want of room, to condense it so much as to make it obscure.

I cannot close this protracted labor, without expressing my obligations to your Excellency, and to your predecessors in office since the commencement of the Geological Survey, for the

kind and liberal manner with which my efforts have been encouraged and my deficiences over looked; for the judicious counsels and instructions which I have received; and for the personal favor and attention with which I have been treated.

Nor would I forget my indebtedness to the other branches of the Government for the liberal patronage and support which they have bestowed upon this enterprise.

Let me here, also, testify to the universal disposition which I have found manifested in every part of the Commonwealth, to forward the objects of the survey. For ten years,—I might in truth say twenty,—I have spent a principal portion of my time in wandering over the State. I have climbed all her mountains. I have penetrated her most sequestered valleys and glens. In short, I have traveled within her boundaries not less than 10.000 miles; not with rail road speed, but rather with a geological, which is nearly synonomous with a pedestrian pace: yet have I everywhere met with a hospitality that has supplied all my wants, and with intelligence enough to understand and appreciate, and a disposition to forward, the objects of my commission. These circumstances have given a deep interest to my geological excursions, and make the retrospect of them among the happiest recollections of my life; while they have greatly exalted my opinion of the kindness, intelligence, and happy condition of our population, and increased my attachment to my native State.

It may not be irrelavent to state, that since Massachusetts begun this geological exploration, no less than eighteen other States of the Union have commenced, and are now actively prosecuting, or have completed, similar surveys: while the Government of the United States, as well as some European Governments, especially that of Great Britain, have followed the same example.

Finally, and above all, I desire to acknowledge and feel my supreme obligations to that kind Providence, which has followed me in all my wanderings, defended me from all serious accident and danger, and enabled me to bring to a conclusion one of the most laborious enterprises of my life. To Him, therefore, I desire to consecrate the fruits of this labor, and the little remnant of strength and of life that remain to me; in the humble hope that they may be accepted; and that upon a retrospect of my days, I may feel that I have not lived entirely in vain.

Respectfully submitted,

*Amherst College, Dec.* 1, 1839. EDWARD HITCHCOCK.

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## *Note.*

It may be proper to say, that the great length of time which has been necessarily consumed in printing the following Report, has enabled me to discover many facts since it was first presented to the Government. These I have not hesitated to incorporate into the work, as the reader will see, without consulting the Government. This statement may, indeed, show that the work is even yet imperfect. But this fact I have no disposition to conceal. If I can flatter myself that I have done something towards developing our subterranean resources, and made the work easier for those who succeed me, I ought not to lay claim to more. E. H.

*Amherst College, April* 1, 1841.

## HISTORY OF THE SURVEY.

On the third of March 1830, the Legislature of Massachusetts passed a Resolve, authorizing and requesting the Governor with the advice of the Council, 'to appoint a Surveyor well skilled in astronomy and in the art of surveying upon trigonometrical principles,—to make a general survey of the Commonwealth, and from such astronomical observations and calculations as may be made, to project an accurate skeleton plan of the State, which shall exhibit the external lines thereof and the most prominent objects within those lines and their locations.'

In Governor Lincoln's Message to the Legislature May 29th, 1830, we find the following recommendation.

'I beg leave to suggest to your consideration the utility of connecting with the Geographical Surveys, an examination of the geological features of the State, with a view to the exhibition of them on the map. Much knowledge of the natural history of the country would thus be gained, and especially the presence of valuable ores, with the localities and extent of quarries, and of coal and lime formations, objects of enquiry so essential to internal improvements, and the advancement of domestic prosperity, would be discovered, and the possession and advantages of them given to the public. I am assured that much has already been gratuitously done, by some eminent professors in our colleges, towards the accomplishment of such a work, and that, at a little expense, it might be completed, and the fruits of their generous labors thus far, be secured to the State. This, however, will require the interposition of your authority in increasing the present appropriation, and permitting an application of it, so far as may be necessary, in the exercise of a sound discretion to the end proposed.'

In conformity with these suggestions, the Legislature, on the 5th of June, 1830, '*Resolved*, That his Excellency the Governor, by and with the advice of the Council, be, and he is hereby authorized to appoint some suitable person, to make a geological examination of the Commonwealth, in connection with the general survey, in order that the same may be inserted on the map which may be published, &c.

On the 26th of June 1830, Governor Lincoln issued a Commission to the author of the following Report, directing him 'to make the geological examination of this Commonwealth, in the manner contemplated by said Resolve, performing such duties relating thereto, as are or may be enjoined upon you; and obeying such instructions as, from time to time, you may receive from the proper authority.'

February 2d. 1831, the Legislature still further authorized His Excellency the Governor, 'to direct the person who is appointed to make a Geological Survey of the Commonwealth, to cause to be annexed to his report on that subject, a list of the native Mineralogical, Botanical and Zoological productions of the Commonwealth, so far as it may be practicable to ascertain the same within the limits of the appropriation already made for this Survey.

A Report on the Economical Geology of the State, with a Geological Map, having been presented to the Government in the beginning of the year 1832, it was ordered to be printed: and on the 24th of March 1832, the Legislature '*Resolved*, that the 600 copies of the first part of the Report on the Geological Survey of the Commonwealth, provided in pursuance of an arrangement made by his Excellency the Governor with the advice of Council, for the use of Government, be delivered to the Secretary of the Commonwealth, and by him be distributed, as follows, viz.

'Four copies to the Governor; two copies to the Lieutenant Governor; One copy to each member of the Council; One copy to each member of the Senate and House of Representa-

tives; five copies to be deposited in the Library of the State: and that the remaining copies be distributed as His Excellency the Governor may direct.'

In the early part of 1833, a full Report was presented, and the Legislature on the 25th of February adopted the following very liberal Resolves:

'*Resolved*, that His Excellency the Governor, be, and hereby is authorized to cause twelve hundred copies of the Report on the Geological Survey of the Commonwealth; including that part of the Report already made, as well as the part hereafter to be made, with the drawings which shall accompany said Report, to be published in such way and manner as he shall deem proper and expedient; and he is authorized with the advice and consent of Council, to draw his warrant upon the Treasurer of the Commonwealth for such sum, or sums, as may be necessary to carry this resolve into full effect.'

'*Resolved*, that the said twelve hundred copies, when published, shall be delivered to the Secretary of the Commonwealth, to be distributed in the following manner, viz: twelve copies to the Governor; six copies to the Lieut Governor; one copy to each member of the Council, Senate and House of Representatives; one copy each to the Secretary, Treasurer, and to each of the Clerks and Chaplains of the two Houses; one copy to each town in the Commonwealth; five copies to be deposited in the Library of the State; two copies each to Harvard, Amherst and Williams Colleges; one copy each to the Theological Seminaries at Andover and Newton; one copy to each incorporated Academy in the Commonwealth; one copy each to the Boston and Salem Atheneums; one copy to the American Academy of Arts and Sciences: one copy to the Antiquarian Society at Worcester; one copy to the Massachusetts Historical Society; one copy to the Boston Society of Nataral History; twenty copies to the Geological Surveyor; and one copy to each person who shall have aided him in preparing the Catalogues appended to the Report; two copies to the Library of the United States; one copy to the Executive of each State in the Union, and the remaining copies to be disposed of in such a manner as His Excellency the Governor shall direct.'

On the 19th of February 1834, the following Resolve was adopted by the Legislature:

'*Resolved*, that his Excellency the Governor with the advice of the Council, be authorized to cause to be printed, under the superintendence of the Geological Surveyor, a new edition of Professor Hitchcock's Report on the Geology of this Commonwealth, and the Atlas accompanying it, with such alterations and additions as may be proposed by the Professor, and approved by the Executive; and that a warrant be drawn on the Treasurer for such sum as may be necessary to defray the expense thereof: provided that the whole expenditure shall not exceed the sum of two dollars and sixty cents for each copy.'

'*Resolved*, that the said five hundred copies, when published, shall be delivered to the Secretary of the Commonwealth, and be distributed in the following manner, viz.

Twelve copies to the Governor; ten copies to the Surveyor; one copy to each of the Chaplains of the Senate and House of Representatives; one copy to each incorporated Lyceum and Atheneum in this Commonwealth; two copies each to the Berkshire Medical Institution, and the Massachusetts Medical College; one copy to each member of the Council, Senate, and House of Representatives, who was not a member of either of those branches of the government for the last year; one copy to each of the permanent Clerks in the office of the Secretary of State, Treasurer, and Adjutant General, two copies to the Pilgrim Society at Plymouth; and the remaining copies to be disposed of in such a manner as the Legislature may direct.'

On the 12th of April 1837, the Governor and Council were authorized and requested to appoint some suitable person or persons to make a further and thorough geological, mineralogical, botanical and zoological survey of this Commonwealth, under his direction, particularly in reference to the discovery of coal, marl, and ores, and an analysis of the various soils of the State, relative to an agricultural benefit.

A Report of 139 pages on the Economical part of the Re-survey was made in the winter of 1838, and printed without any special order. In December 1839 the Final Report was presented, and the Governor was authorized to procure the publication of 1500 copies by a Resolve passed April 9th 1839, which were to be distributed as follows.

*Resolved,* That the said copies, when published, be delivered to the Secretary of the Commonwealth, to be distributed in the following manner: twelve copies to the Governor; six copies to the Lieut. Governor; one copy to each member of the Council, Senate, and House of Representatives; one copy each to the Secretary, Treasurer, and to each Clerk and Chaplain of the two Houses; one copy to the Secretary and one to each member of the board of Education; twenty copies to the Geological Surveyor, and ten to each Commissioner appointed under the resolve of April 12th, 1837; five copies to be deposited in the library of the State; one copy to each town in the Commonwealth; two copies each, to Harvard, Amherst, and Williams colleges; one copy each to the theological seminaries of Andover and Newton; one copy to each incorporated Atheneum, Lyceum, and Academy, in the Commonwealth; one copy to the American Academy of Arts and Sciences; one copy to the Antiquarian Society at Worcester, and one to the Pilgrim Society at Plymouth; one copy to the Massachusetts Historical Society, and to every other incorporated historical Society in the Commonwealth; one copy to the State Lunatic Hospital at Worcester; one copy to the Boston Society of Natural History; one copy to the Essex County Natural History Society; one copy each to the Massachusetts and Salem Charitable Mechanic Associations; one copy to the library of the East India Marine Society, in Salem; two copies to the library of the United States; one copy to the Executive of each State in the Union; one hundred copies to be placed at the disposal of the Governor, and the remainder to be subject to the further order of the Legislature.

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## *Errata.*

Only the following Errors of much importance have yet been noticed. Many in orthography and punctuation will undoubtedly be found; but it is hardly necessary to notice any here, unless they are such as to mislead the reader.

p. 49, line 20 from top, for 241 and 242, read 185 and 187: make the same correction in lines 25 and 28 from top.

p. 125, in the caption of the composition of crenic acid, transpose *oxygen* and *carbon*.

p. 325, line 17 from top, for *at* read *as*.

p. 358, line 5 from bottom, after *abutments* add, *and piers*.

p. 423, at top, for Plate 55, read, Plate 54.

p. 425, line 14 from top, for Plate 55, read, Plate 54.

p. 807 against No. 2591, for *Wrentham*, read *Mansfield*: and against No. 2592 for the right hand *do*, read *Wrentham*.

## POSTSCRIPT.

In sciences pursued with so much zeal and ability as Geology and Chemistry at the present day, the lapse of a year often brings out important discoveries. During the longer period in which this Report has been in press, some developments have been made important enough in my opinion to demand a Postcript. They are inserted at the beginning of the Report, both because of their importance, and because of the well known fact that this is the last part of a work that is printed.

### *New Work on Organic Chemistry.*

Professor Liebig of the University of Giessen, has recently published a work on *Organic Chemistry in its applications to Agriculture and Physiology*, which contains many new views in relation to the nutrition and development of plants. All these views, coming as they do from one of the most distinguished organic chemists living, will be examined by scientific men with great respect, and some of them adopted at once as obvious discoveries and improvements. He seems to have proved that the atmosphere contains ammonia, and justly imputes much to its agency in the growth of plants. Indeed, he makes nitrogen much more important in vegetation than has been supposed. He maintains that the favorable influence of gypsum results from its fixing the ammonia of the atmosphere in the soil by converting it into a sulphate. The important principle suggested and defended by Dr. Dana, and confirmed by all the analyses given in this Report, that phosphates exist naturally in all soils, is also maintained by Liebig, without any knowledge of course that the same view had been taken on this side of the Atlantic. His suggestions respecting the rationale of a rotation of crops, and many other points in practical agriculture, are ingenious and important.

As to the manner in which plants are nourished, Liebig adopts the opinion of Raspail, that their carbon is derived wholly from the imbibition of carbonic acid, either from the atmosphere or the soil. He denies that they absorb geine, or any of its compounds, as nourishment; and he supposes that the geine (humus, or humic acid,) acts only as a means of generating carbonic acid by the changes which it undergoes. It is not my intention to go into any argument on these points in this postscript. But it is a little curious, that Liebig, in attempting to show that there are no means in soils for dissolving more than an infinitessimal quantity of geine, should have overlooked the two most important means of its solution. He supposes that rain water is the only agent in this work. But growing plants have the power of decomposing silicates, and thus of setting free potassa and other bases eminently adapted for the solution of geine. Again, the changes which geine undergoes in the soil produce a great quantity of water, sufficient, according to Nicholson's Journal, to cause an evaporation of 5000 pounds per hour from a well manured acre: quite equal to that resulting from the most copious rains. (*See Webster's Liebig, p. 398.*)

The views of Dr. Dana on these points, I ought perhaps to remark, are those which have most widely prevailed among scientific men in modern times, viz. that plants derive their nourishment partly by absorption from the atmosphere, and partly by taking up soluble matters from the soil. He admits even, that they may absorb carbonic acid by their roots; nor does he decide upon the exact proportion in which nourishment is derived from these different sources. Indeed, it would not be surprising if it should appear, that plants have such a power of adapting themselves to different circumstances, that they might sometimes sustain themselves exclusively from the atmosphere, and sometimes from the soil: sometimes by carbonic acid alone, and sometimes by geine alone. If such be the case, it might reconcile some of the conflicting experiments and opinions on this subject.

### *Organic Matters in Soils.*

Although chemists have long been agreed that several distinct compounds exist in the organic matter of soils, they are not agreed as to their exact number. According to Dr. C. T. Jackson, Berzelius, the distinguished chemist who first proposed the term geine, in a late edition of his Chemistry has dropped that term, and substituted for it that of humic acid. He has also substituted *humin* for carbonaceous mould. He still employs the terms crenic and apocrenic acid, and extract of humus; and these substances, with humic acid and humin, and occasionally traces of glairin, embrace all yet detected in the organic matter of soils, which he denominates humus. This humus corresponds to the geine of Dr. Dana, when he uses that term agriculturally. He then embraces in it crenic and apocrenic acid, humic acid, and humin; which he regards as forms of geine; divided by him into two classes, the soluble and insoluble. It is in this sense that the term geine is used in Dr. Dana's rules of analysis given in this Report. It is true, when he uses the term chemically, he means the same by it as Berzelius does by humic acid: though as the extract of humus and humin of the same author, do not differ in composition from the humic acid, these also are embraced in geine. Dr. Dana, however, would not have given his views concerning the chemical nature of geine, had he not been requested: for he does not regard this essential in treating the subject agriculturally. In a letter to Mr. Colman, the Agricultural Surveyor, he says, "whether we consider geine as a simple substance, or composed of several others called crenic, apocrenic, puteanic, ulmic acids, glairin, apotheme, extract of humus, or mould, agriculture ever has considered it, and probably ever will consider it one and the same thing, requiring always similar treatment to render it soluble when produced; similar treatment to render it an effectual manure."

According to these views, whose truth is founded not on theory but experience, we can see how analyses of soils may be usefully conducted according to Dr. Dana's rules, even though there be a diversity of opinion among learned men as to the chemical nature of the organic matter of soils, and the mode in which plants are nourished. For whether geine consists of one or twenty substances, and whether it be directly imbibed by plants, or only furnish carbonic acid, the fact still remains equally true, that the fertility of a soil depends in a good degree upon the amount of soluble geine which it contains.

These remarks seemed to me important to prevent a misapprehension of the language and principles of Dr. Dana in this Report.

1a

## *Distribution of Sea Shells.*

In Dr. Gould's Report on the Mollusca of Massachusetts just published, a fact of no small geological interest is given respecting the marine shells found on the opposite sides of Cape Cod. I present it in his own language.

"The distribution of the marine shells is well worthy of notice as a geological fact. Cape Cod, the right arm of the Commonwealth, reaches out into the ocean some fifty or sixty miles. It is no where many miles wide, but this narrow point of land has hitherto proved a barrier to the migrations of many species of *Mollusca*. Several genera and numerous species, which are separated by the intervention of only a few miles of land, are effectually prevented from mingling by the Cape, and do not pass from one side to the other. No specimen of *Cochlodesma*, *Montacuta*, *Cumingia*, *Corbula*, *Ianthina*, *Tornatella*, *Vermetus*, *Columbella*, *Cerithium*, *Pyrula* or *Ranella*, has as yet been found to the north of Cape Cod; while *Panopea*, *Glycymeris*, *Terebratula*, *Cemoria*, *Trichotropis*, *Rostellaria*, *Cancellaria*, and probably *Cyprina* and *Cardita*, do not seem to have passed to the south of it. Of the 197 marine species, 83 do not pass to the south shore, and 50 are not found on the north shore of the Cape. The remaining 64 take a wider range, and are found on both sides."

## *Report on the Fossil Footmarks.*

In my account of the fossil footmarks in the Connecticut valley, I have quoted the opinion of two distinguished European geologists concerning them. I have now the satisfaction of giving the views of several eminent geologists of our own country on the same point. At a meeting of the Association of American Geologists in Philadelphia, in April 1840, a Committee was appointed "to visit the localities and report their conclusions at the next meeting." At that meeting, held in the same city in April 1841, the following Report was presented.

## *Report on the Ornithichnites or Footmarks of extinct Birds in the New Red Sandstone of Massachusetts and Connecticut, observed and described by Prof. Hitchcock, of Amherst.*

The undersigned, forming the Committee to whom the subject of the origin of the Bird tracks of Professor Hitchcock was assigned, beg leave to present the following brief Report. It may be well previously to state, that the object of the meeting in appointing this Committee was founded solely upon the desire to produce if possible unanimity of opinion, there being a few of the members who dissented from the views published by Professor Hitchcock. In our country the subject, as it undoubtedly ought, had attracted considerable attention. It had been very favorably received and republished in Europe; and from its great importance to Palæozoic Geology, an attempt should be made to settle the question: for were the views of our highly respected member correct, we were made acquainted with the earliest period in which biped animals existed, whose footmarks were analogous to, if not identical with those of the tread of birds: On the contrary, if wrong, we were presented with another class of facts, which show that certain appearances supposed to belong solely to animal life, were held or presented by the vegetable kingdom likewise. We shall now state in a few words, what we suppose are the general facts upon which Prof. Hitchcock's views were founded, and then the facts of those who assumed the opposite opinion. The first and most obvious impression upon the mind on looking at the indentations or marks, is their tri-partite form, resembling the tread or footmarks of those kinds of Birds, which have three toes, the fourth one being rudimental, and are referrible to no other known kind of animal. The tracks or footmarks in several localities are arranged in a determinate order, like those of a bird or fowl, moving in a straight line: the toes or marks in all such cases being alternate; that is, if the right foot be presented on the rock, the left would next follow, and thus right and left in regular succession, sometimes with many repetitions. In other instances the footmarks presented no determinate direction or order, as might naturally be supposed of a bird or any other animal having no particular place or object in view. In all cases where a succession of tracks was observed, there was an uniform correspondence as to size, and considerable regularity as to distance, between the tracks. Whatever deviations were observed, they were not greater than might be supposed to take place in animals possessed of voluntary motion. On some surfaces not unfrequently one or more different kinds of tracks were exposed, belonging, as was reasonably conjectured, to different species and genera of Ornithichnites. That the slaty material of the rock showed that the impressing body possessed force or weight, for frequently the thin layers or laminæ were bent downwards for an inch or more, and that the mud of which the slate was formed was of a highly adhesive or tenacious character. In all cases the footmarks or part impressed, was the fixed part of the rock; the part removed when the lower side was turned upwards, showed the cast or what corresponded with the toes or foot. That no trace of any organic matter could be perceived occupying the cavity or mould, the cast or part in relief being in all respects like the material of the rock of which it formed a part. Finally, that the footmarks belonged to a group of rocks which must be considered to have been produced by the same general causes which gave rise to the New Red Sandstone of Europe, and referrible only to that Sandstone. This Sandstone presents footmarks in many localities, though comparatively but a few years have elapsed since attention has been called to them. Some of the specimens have reached this country, and had they not, the information is well given by Dr. Buckland in his Bridgewater Treatise. The most remarkable of these footmarks is that of the Chirotherium from the quarries of Hessberg near Hildburg hausen in Saxony, and greatly resembles a fleshy human hand. These in the drawing and in the specimen which we have seen, are alternated right and left. Other footmarks have been observed by Mr. Link in the same sandstone, he having made out four species of animals, some of which are conjectured to belong to Gigantic Batrachians. Near Dumfries the footmarks of animals, probably tortoises, were obtained from the same sandstone: but as yet no tracks like those of New England have been discovered.

The facts, &c. which led to a different conclusion are these. First, that the forms assumed by fucoidal plants were numerous and imitative; some resembling the tail of a rooster, the *Cauda Galli*. Another which was like unto a large claw or paw, and which may have been a lusus naturæ, and the two specimens on the table of the Association which present in relief a distinct tri-partite form. There as they all appertain

to rocks of great antiquity in comparison with those of New England, it appeared more reasonable to believe that there might be resemblances as perfect as the fossils with a tri-partite character, were but approximations to the forms in question. That no trace of organic matter could be discovered by the eye, in the greater number of the Fucoides. In some such as the Harlani, they have been seen to be made up of small pebbles, presenting no little difficulty not to the manner only in which the organic matter was replaced, the external form being complete, but the nature of their material which could make so definite an impression and preserve its form entire. There are other facts which showed resemblance such as that the part in relief, was the part removed when the fucoide was attached to sandstone at its upper part. It may also be stated that the appendages to the heel of some of the New England tracks, might have been caused by a bird whose legs were feathered, but not to a wader, and they favoured their vegetable origin, for the appendages might readily be conceived to be either leaves or radials or both. From a comparative examination of the facts on both sides, your Committee unanimously believe that the evidence entirely favours the views of Prof. Hitchcock, and should regret that a difference had existed, if they did not feel assured it would lead to greater stability of opinion. To liken things to what we know in the nature of mind, the error from this tendency increases with ignorance and diminishes as knowledge increases, so that He that knoweth all things, as is self-evident, can commit no error when following this instinct of his being. The discoveries of Prof. Hitchcock were published at a period when the mind of those who embraced the negative side of the subject was preoccupied with the anomalous vegetation which many of the Silurian rocks of New York abound and to which provisionally the name of fucoid had been given. From their imitative character, and from finding a few specimens presenting a tri-parlate or tri-furcate form, &c. it appeared not only possible, but probable, that the impressions from Massachusetts and Connecticut were with greater propriety referrible to fucoidal bodies, than to those which Prof. Hitchcock had assigned them. We may here remark how essential it is that truth, or the facts which make manifest any truth, should first be presented to us, so readily is the mind impressed when not pre-occupied, and when a strong impression is made be it ever so false, it is no easy matter to free ourselves from it. From this circumstance we can readily forsee the advantage which future generations will possess over those of the present and especially those of former times. As the progress of knowledge is certain, each day will lessen error and enlarge the domain of truth, and should man be true to his permanent interests, error will finally cease to have existence.

HENRY D. ROGERS,
LARDNER VANUXEM,
RICHARD C. TAYLOR,
EBENEZER EMMONS,
T. A. CONRAD.

## *Glacio-aqueous Action between the Tertiary and Historic Periods, denominated in my Report, Diluvial Action.*

Since the Section in this Report on Diluvium was written, I have been favoured, through the kindness of Professor Silliman of Yale College, with the perusal of a recent work by Professor Agassiz on Glaciers and Glacial action, entitled *Etudes sur les Glaciers*. I am indebted, also, to Dr. J. Pye Smith of London, for an abstract of three papers on the same subject, read last autumn before the London Geological Society, by Agassiz, Buckland, and Lyell. By the labours of these distinguished men, the whole subject of diluvium has been made to assume an aspect so new and interesting, that I am unwilling my Report should go out of my hands unaccompanied by a brief view of the facts and inferences concerning it. Perhaps I cannot better accomplish this object, than by giving, in the first place, an outline of the glacial theory, and its application to this country, in an extract from an Address recently published, which I gave before the Association of American Geologists at Philadelphia in April 1841.

"Beyond such independent inferences as these, (which had just been stated,) I confess, I have been of late years unwilling to go; and have regarded the numerous theories of diluvial action that have appeared, only as ingenious hypotheses. But it is well known that the Glacier Theory, originally suggested by M. Venetz, and subsequently by M. Charpentier, and more fully developed of late by Agassiz, is now exciting a great interest in Europe. To say nothing of geologists in this country, who have expressed themselves favorably towards it, it is surely enough to recommend it to a careful examination, to learn that such men as Agassiz, Buckland, Lyell, and Murchison, after long examination, have more or less fully adopted it; though on the other hand, it ought to be mentioned, that such geologists as Beaumont, Whewell, Sedgwick, Mantell, and others, still hesitate to receive it."

"In a country like ours, where no glaciers exist except in very high latitudes, and with the very indefinite accounts, which have hitherto been given of those in the Alps, it is not strange that this attempt to explain the vast phenomena of diluvial action by such an agency, should appear at first view, fanciful, and even puerile. But the recent work of Agassiz, entitled "*Etudes sur les Glaciers*," gives a new aspect to the subject. It is the result of observations made during five summers in the Alps, especially upon the Glaciers, about which so much has been said, but concerning which so little of geological importance has been known. Henceforth, however, glacial action must form an important chapter in geology. While reading this work and the abstracts of some papers by Agassiz, Buckland, and Lyell, on the evidence of ancient glaciers in Scotland and England, I seemed to be acquiring a new *geological sense*; and I look upon our smoothed and striated rocks, our accumulations of gravel, and the "*tout ensemble*," of diluvial phenomena, with new eyes. The fact is, that the history of glaciers is the history of diluvial agency in miniature. The object of Agassiz is, first, to describe the miniature, and then to enlarge the picture till it reaches around the globe."

"The glaciers are vast masses of ice, formed of melting and freezing snow, which are sent out from the summit of the Alps, by the force of expansion into the valleys below, sometimes to the distance of 12 or 15 miles. Those elevated and wide *plateaux*, called in Switzerland *Mers de Glace*, exhibiting only one sheet of ice, through which the crests and summits of the mountains sometimes rise like volcanos, are the grand source, or *birth-place*, of the glaciers. In their descent they plough their way through the soil, pile up pebbles and sand along their sides and at their extremities, and even upon their backs, which, upon the retreat or melting of the glaciers, constitute *moraines*, and correspond exactly in composition and shape to those

accumulations of gravel and bowlders that have been ascribed to diluvial action: The stones and sand frozen into the lower surface, also, like so many fixed diamonds, smooth and furrow the surface of the rocks in precisely the same manner as they appear over all northern countries. Vast blocks of stone are also conveyed without attrition, by the advance of the glaciers, and lodged in peculiar situations."

"From year to year the evidence has been increasing of the prevalence of intense cold in northern regions in the period immediately preceding the historic. The elephants and rhinoceros found in the frozen mud of Siberia, the arctic character of the few organic remains found in the post-tertiary strata of Scotland and Canada, as described by Lyell and Bowman, and of the borders of Lake Champlain, as described by Emmons and Conrad, and the vast extension of the ancient moraines in the Alps, are the evidence from which Agassiz infers that in that period all northern countries were covered with a vast sheet of ice, filling the valleys and extending southerly as far as diluvial phenomena have been observed. Glaciers would thus be found on mountains of moderate alttitude; and, indeed, he supposes that all the northern part of the globe might have constituted one vast *Mer de Glace*, which sent out its enormous glaciers in a southerly direction; thus giving the same direction to the drift and striæ on the rocks. As these vast masses of ice, when the temperature was raised, melted away, immense currents of water were the result, which would lift up and bear along huge icebergs, whereby extensive erosions would be produced and blocks of stone be transported to great distances. Subsequently, lakes would be formed, where moraines had produced barriers, and clay and sand would there be quietly deposited by the waters which would be ultimately drained by the wearing down of the barriers of detritus."

"It is doing injustice to this theory to attempt so brief a description of it. A detailed account of existing glaciers which cannot here be given, forms the best preparation for a just appreciation of the theory. Admitting its truth in the main, let us see how it applies to the phenomena of drift in this country."

"In the first place, it explains satisfactorily the origin of those singular accumulations of gravel and bowlders, which we meet with almost everywhere in the northern parts of our country. I cannot doubt but that these are ancient moraines, just such as exist in Scotland and England. Were this the proper place, I could point out a multitude of localities of these, most of which have been a good deal modified by subsequent aqueous agency: but some of them retain the very contour which they had, as the ice melted away. The lateral moraines are perhaps most common, especially if with Dr. Buckland we regard our terraced valleys as modifications of these; but I am confident that in our mountain valleys, the terminal and medial moraines are not infrequent. I have long been convinced that the agency of ice is essential to explain these accumulations; but I was not aware that their antitypes existed in the moraines of the Alps."

"In the second place, this theory explains in a most satisfactory manner, the smoothing, polishing and furrowing of the rocks at different altitudes. All these effects are perfectly produced beneath the glaciers in the Alps; nor can I conceive of any other agent, by which the work could be executed. It certainly was not done by currents of water alone."

"In the third place, it explains the transportation of bowlders, and their lodgment upon the crests and narrow summits of mountains; and that often without having their angles rounded."

"In the fourth place, it accounts for the existence of deposits of clay and sand above the drift. For it furnishes the requisite quantity of water to fill the valleys, and the means of damming up their outlets for a season."

"In the fifth place, it shows us why these deposits of clay and sand are almost completely destitute of organic remains, either of animals or plants, although centuries must have been consumed in their formation."

"In the sixth place, it accounts for some rare and peculiar phenomena connected with diluvial action, which seem to be inexplicable on any other known principle. I shall name only two. The first is, that the northern slopes of some of the mountains of New England, although quite steep, and their summits rounded, exhibit scratches and furrows, which commence several hundred feet below their tops, and pass over them without losing their parallelism; and yet the situation of the drift shows that these markings were made by an ascending, not a descending body. Such might be the effect, if the whole surface of the country were covered by a thick sheet of ice, expanding in a southerly direction. Of the other case, I have met with two examples in New England, and know not that they have been noticed elsewhere. In these cases the perpendicular layers of argillaceous and hornblende slate, covered in one case by 15 or 20 feet of drift, have been fractured to the depth of 10 or 15 feet, so as to be more or less separated, and so as to produce horizontal fissures, which are filled by mud; while the laminæ of the rock are inclined at various angles. In short, it seems as if an almost incredible force had been exerted upon the surface, in an oblique direction. Such a force might be exerted by an immense mass of ice, in the process of expansion; but I know of no other source from which it could have been derived." *(See Fig. 83, p. 396, and Fig. 114, p. 560, of this Report.)*

"On the other hand, there are features in the phenomena of diluvial action in this country, which are explained by this theory, in a much less satisfactory manner. One is, the southerly direction which our drift has taken, and the great distance to which it has been carried. It cannot be conceived that any single glaciers should have expanded several hundred miles in a southerly direction, especially over a surface which could have had scarcely no southern slope. Even if we admit a "Mer de Glace" in the northern regions so lofty, as in the beginning of the work to send glaciers a vast distance, yet the force seems to have continued to operate in the same austral direction, even to the bottom of our valleys. It is, however, probably true, that the great mass of our drift will be found within 15 or 20 miles of its origin, and that which occurs at greater distances may, perhaps, have been transported by powerful currents of water. It is almost certain that the sheets of ice which covered the surface according to this theory, must have been at least 3000 or 4000 feet thick; because our mountains to that height have been swept over. Now, if as Agassiz and others suppose, the fall of temperature at the beginning of the glacial period was very sudden, why may not the return of the heat have been equally sudden? If so, the most powerful debacles must have been the result;* and as the ice would disappear most rapidly along its southern border, perhaps in this way a

* A curious example illustrative of this point has just been communicated to me by Rev. Justin Perkins, American Missionary at Oroomiah, in Persia, not far from Mount Ararat, in a letter of Nov. 6th, 1840. In giving an account of two very powerful earthquakes experienced on and around the mountain in the summer of last year, he says; "the vast accumulation of snow which had been increasing on and about the top of the mountains for centuries, was broken into pieces, and parts of it shaken down on the

current in that direction may have been produced. And yet, I confess that I regard this theory more defective in not furnishing an adequate cause for the southerly course of our drift, than in any other point."

"I find another difficulty in explaining satisfactorily by this theory, how drift could have been often carried from lower to much higher levels; as it has been sometimes, without doubt. Thus, the Silurian rocks of New York and the quartz rock in the western parts of Massachusetts, have been carried over Hoosac and Taconic mountains and the Highlands of New York. It is easy to conceive how an immense sheet of ice, by its expansive power, should force portions of its mass to ascend declivities, of a few hundred feet; but not so easy to imagine them thus forced upward 1000 or 2000 feet.

"Another difficulty results from the fact, that some of the most remarkable of our moraines are found, not in valleys, but on the sea-coast, some of them 50 and others 100 miles distant from any mountain, much higher than themselves. I refer to those remarkable conical and oblong tumuli of drift, sometimes more than 200 feet high, which occur in Plymouth and Barnstable Counties in Massachusetts. I see nothing in this theory that will explain such astonishing accumulations in such circumstances; and yet their existence may not militate against its truth. For even the present mighty glaciers of the Alps, may give us but a faint idea of the advance and retreat of a sheet of ice thousands of feet thick."

"I do not mention these difficulties, (to which I might add more,) as any strong evidence against this theory. For so remarkably does it solve most of the phenomena of diluvial action, that I am constrained to believe its fundamental principle to be founded in truth. Modifications it may require: for it would be strange indeed, if it had already attained perfection, even in the skilful hands that have thus far formed and fashioned it. But I can hardly doubt that *glacio-aqueous* action has been the controlling power in producing the phenomena of drift. Having hovered so long over the shoreless and troubled ocean of uncertainty and doubt, I may be too ready to alight on what looks like *terra firma*. But should it prove a Delos, I have only to plume my wings again, when it sinks beneath the waves."

It may give a more definite idea of the nature of glaciers and of some of the phenomena connected with them, to insert a few cuts, copied on a reduced scale from the splendid drawings accompanying the *Etudes sur les Glaciers* by Agassiz. Fig. 276, exhibits the glacier of Aletsch, one of the largest in the Alps, where it enters the lake of Aletsch which it has formerly caused to overflow with wide spread havoc. Large blocks frequently break off from this glacier and float about as icebergs in the lake.

Fig. 276.

*Glacier and Lake of Aletsch.*

Fig. 278, exhibits the lower extremity of the Glacier of Viesch, with a distinct terminal moraine, which at the sides is connected with lateral moraines. From beneath the Glacier issues a stream of water, as is always the case in summer. This has worn a channel into the rocks below the glacier, and the surface of those same rocks is smoothed and striated by the former action of glaciers; so that here is exhibited glacial and aqueous action side by side. The conical bodies on the top of the glacier are needles of ice called *Aiguilles*, formed by the inequality of the surface beneath, and the melting of the ice above They are shown also on Fig. 277.

sides of the mountains in such immense quantities, that (it being midsummer and the snow descending down as far as a warm climate and suddenly melting,) torrents of water came rolling down the remainder of the mountain, and flooded the plain for some distance around its base."

Fig. 277.

*Glacier of Viesch in the Alps.*

In Fig. 277, we have a view of the upper part of the glacier, of Viesch, as it proceeds from the distant *mer de Glace*, and winds through the long valley. At its sides may be seen lateral, and on its top, medial moraines; considerably disturbed, however by the serpentine course of the valley.

Figs. 279 and 280, represent smoothed and striated masses of schistose serpentine, produced by the expansion of the glacier. Fig. 279, shows two sets of scratches, crossing each other at a considerable angle. Yet the striæ belonging to each set preserve their parallelism most perfectly.

Any one conversant with the smoothed and striated rocks of this country will be struck with their exact resemblance to the above. It is not unusual also, to meet with surfaces with two sets of striæ diverging slightly, as in Fig. 280. This is often the case, according to Professor Locke, upon the polished limestones of Ohio. Fig 281 is a case of this kind, copied from the crest of Mount Monadnoc in New Hampshire. The two sets of scratches diverge only 10,° and it is not common to see a much greater divergence.

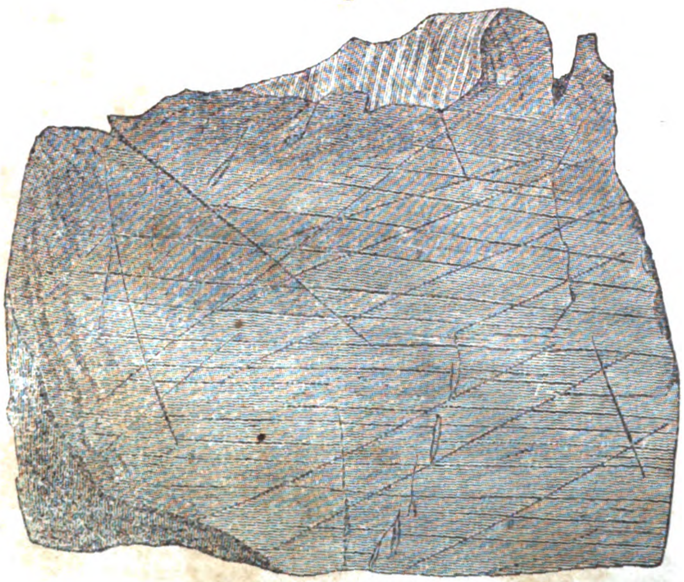
Another effect of glaciers has its counterpart among our diluvial phenomena. The ice so rounds off the angles of rocks as to give them an embossed form; and hence such rocks in the Alps were called by Saussure, *Roches moutonnees*. An example of this effect,—though less striking than others exhibited on the plates of Agassiz, (*Etudes sur les Glaciers*,) is shown on Fig. 277, at its lower part, and on Fig. 278 more distinctly. This same appearance is trequent upon the rocks of Massachusetts: but one of the most distinct examples that I have ever seen, occurs on Mount Monadnoc in New Hampshire. A large part of the crest of that mountain, and its northern and northwestern slopes, are covered with these protuberant and rounded rocks, whose surfaces often show distinct striæ. An attempt is made in Fig. 282, to represent the aspect of one spot about 5 rods square on the crest of the spur of Monadnoc that runs southwest from the body of the mountain. In taking the sketch the eye was directed southeasterly, which was the course there taken by the glacial agency. Hence the protuberances appear more like spherical domes than they are in reality; because they are generally much longer in a southeast and northwest direction than in any other. This spot is not less than 600 or 700 feet below the summit of the mountain; but the same appearance is common even almost to the apex.

On page 389 of this Report, I have given a brief account of diluvial action on Monadnoc, derived from my assistant, Mr. Abraham Jenkins, Jr. The interest which his description excited, has led me within a few days past to visit that mountain, and I found it prolific in the marks of former glacial action. It consists of a ridge of mica slate, running nearly S. W. and N. E. near whose center rises a vast pile of naked rock, several hundred feet above its northeastern and southwestern wings, which are also in a great measure naked. On almost every part of it, from its base to its summit, it bears the marks of a powerful abrading agency: and the region around the mountain, the hills as well as the valleys in its vicinity, abound with striated rocks, angular blocks of stone, and occasional moraines. The direction of the markings around Monadnoc and upon its southeastern part, is nearly N. W. and S. E.; but near the summit of the mountain they approach more nearly to the meridian, as near sometimes as 10° by the compass.

Fig. 278.

*Glacier of Viesch, with terminal and lateral Moraines.*

Fig. 279.

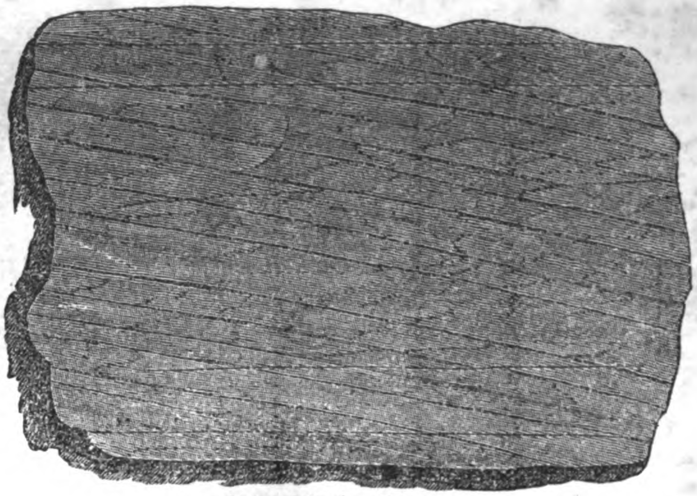


*Rock striated by Glaciers.*

Fig. 280.

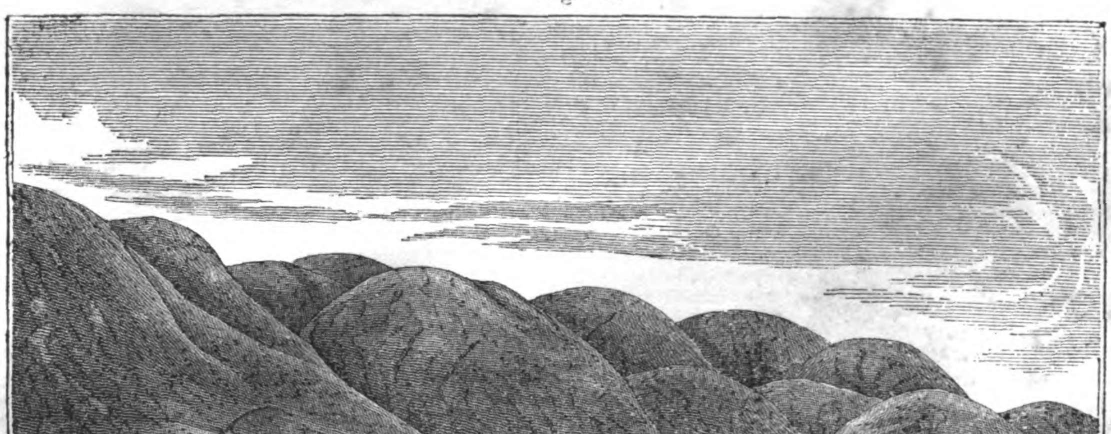
*Rock striated by Glaciers.*

Fig. 281.



*Striated Rock: Monadnoc.*

Fig. 282.



*Embossed Rocks (Roches moutonnees): Monadnoc.*

There are several peculiarities in what have been called the diluvial phenomena of this mountain, with which I should have been exceedingly perplexed, had I not read the recent *Etudes sur les Glaciers* by Agassiz. The striæ on the rocks are not as distinct as in many other places, and the difficulty of observing them is increased by the fact that over a considerable portion of the southwest part of the mountain, the strike of the laminæ of slate coincides very nearly with that of the scratches. Nevertheless, they may generally be distinguished by the practised eye, and on a large part of the mountain they cross the edges of the slate at a considerable angle. They are frequently visible on the sides of the ledges; and on the north side of the principal peak, they are sometimes seen on slopes from 20° to 70°. And what is still more unusual, they are seen on the southeast side of the principal summit, where the slope is steep, and several hundred feet below the top. But the *roches moutonnees* are the most striking peculiarity of the phenomena under consideration. Almost every part of the mountain, except its steep southeasterly side, is covered by these irregular rounded protuberances, which have almost every possible form; but their longer axis corresponds almost invariably with the direction of the grooves and striæ. Looking in a southeasterly direction they sometimes have the appearance represented on Fig. 282; but looking at them from other positions, they considerably resemble the swells of the ocean in a calm day after a storm. Frequently too the effects of ice in recent times, is seen in breaking up the surface of the rock more or less into fragments. If we face the northwest, even when among these rounded rocks, we see but little of the *moutonnees* appearance, because their southeastern extremities are not rounded: and there, indeed, (as at a spot few rods east of the summit of the mountain,) we see where large masses of the rock have been forced out of their places and carried away. Few loose transported blocks now remain upon the mountain.

The facts stated above relative to the occurrence of striæ on the north and south slopes of Monadnoc, might lead to the conclusion that they were the result of glaciers sliding down each way from the summit. But the fact that the *roches moutonnees* are rounded only upon their northwestern side, shows that the force which has produced these effects had a southeasterly direction. Indeed, I see no way to avoid the conclusion that the ice, which probably was the agent, must have been forced upward over the top of this mountain. I descended on the north side only a few hundred feet, but could see downward nearly to the bottom, and the same appearances presented themselves as near the top. Were the whole of the surrounding region covered with a vast sheet of ice, I can easily conceive how its expansion might have accomplished such a work. Indeed, so nearly irresistible must such a force have been, that either the mountain must have been crowded out of its place, or the ice have been swelled upward and forced over it. Such an operation must have broken the ice considerably, and this may explain the irregularity of its action towards the summit of the mountain, which is greater than I have witnessed in any other place.

If these views are correct, we cannot probably infer that the sheet of ice which covered New England was quite as thick as the height of Monadnoc; because it might have been swelled up considerably at this place. But the marks of its action at the top of the mountain are too striking to suppose the swell to have been very much above the general surface: otherwise the ice would have been tilted over and left no trace of its action. The downward force at the top must have been nearly as great as in any other part, and therefore a great thickness of ice must have been forced over it.

The important bearing of these details upon the theory of glacial action, is the reason I have given them; although Monadnoc lies a few miles out of the limits of the state. But whatever glacial action has taken place there, we may be quite sure has extended into Massachusetts. And indeed, I have pointed out similar phenomena there in the following Report.

## *Moraines.*

After reading the work of Agassiz on Glaciers, and an abstract of the papers of Agassiz, Buckland, and Lyell, on the evidence of former glacial action in Scotland and the north of England, I cannot doubt but ancient moraines are scattered all over New England. The most remarkable of these I have described and figured in this Report. (See Wood Cuts, figs. 15, 19, 73 and 74, and Plate 3.) In the work of Agassiz I do not indeed find a description of any of those singular insulated or grouped tumuli of sand and gravel, which are so common in this country, and some of which are shown in the drawings above referred to. But it cannot be doubted that Dr. Buckland describes the same phenomenon in Scotland, when he says that "thirty or forty round-topped moraines, from 30 to 60 feet high, are crowded together like sepulchral tumuli," and he adds, that "they exactly resemble some of the moraines in the valley of the Rhone, between Martigny and Loek." Similar accumulations are common, according to him, in Scotland. I regret that he has not described under what peculiar circumstances such singular moraines are formed: for I own myself perplexed to conceive how: especially as the largest examples occur with us far away from any elevated land. I refer to those in Plymouth and Barnstable Counties. And yet, I shall be likely to regard the fact, that without any definite knowledge of the action of glaciers, I have in this Report called in the aid of ice to explain these mounds of gravel and sand, as some presumption in favor of their glacial origin. But how came such enormous moraines to be found in the low and comparatively level country where they exist? Is it possible that the whole of Cape Cod is nothing but a vast terminal moraine, produced by a glacier advancing through Massachusetts Bay, and scooping out the materials that now form the Cape? In this case the moraines at Plymouth and Truro would form a part of the lateral moraines, and probably most of Nantucket and Martha's Vineyard might be regarded as moraines of the same glacier, when it extended farther south. But the fact that laminated clay occurs so often upon the Cape, is a strong objection to such an hypothesis. The occurrence of so many ponds in connection with the moraines of Plymouth, Sandwich, and especially Falmouth, is readily explained by the glacier theory; since such effects are often thus produced in the Alps.

My attention was called to the new views of this subject, in season to mark on the proof sheet of Plate 53, which exhibits some of the phenomena of drift in Massachusetts, the most remarkable examples of moraines occurring in the State. These have, indeed, been described under another name in the following Report. It will be seen that many of the most remarkable of these occur far away from mountains and valleys, in the eastern part of the State, as at Truro, Sandwich, Falmouth, Plymouth, Wrentham, and Groton Interesting examples exist, also, in Andover; but here the country is more uneven. As we proceed to the more hil-

ly parts of the State, it must be confessed that the moraines are the largest and most striking at the foot of the mountains, and especially near gorges in the valleys. The more elevated parts of country are, indeed, often thickly strewed over with loose blocks; but generally they are not much rounded, and appear as if they resulted from medial moraines, very much scattered. Essex county abounds with such examples, particularly on Cape Ann. (See Figs. 27, 28.) They abound also over the greater part of Worcester county, particularly as we ascend the western slope of Worcester valley.

So far as I have been able, I have recently re-examined the accumulations of gravel and bowlders in the State, to see whether they could be explained by glacial action. I find it often very difficult to recognise the different sorts of moraines; but think the lateral moraines most common and distinct. Thus, along the whole extent of the great valleys of Connecticut and of Berkshire county, we find lateral moraines evidently considerably modified and enlarged by those at the *debouche* of the smaller lateral valleys. The moraine on the western side of these great valleys is far less striking than on their eastern side. I cannot explain this fact, except by saying that the force which formed these moraines, acted in a southeasterly direction, so as to cross the principal valleys (as a glance at Plate 53 will show,) at a considerable angle. But it is not so easy to see how this is consistent with the idea that the moraines were formed by glaciers passing longitudinally through these valleys.

In the south part of Montague and northwest part of Leverett, is an interesting group of moraines. A narrow valley intervenes here between Mount Toby on the west, and the primary hills on the east; and it is at the entrance of this valley on the north, that we find both terminal and lateral moraines. The most southerly of these are pushed a considerable distance into the valley, the detritus (mostly gravel,) showing a northern origin. But the largest accumulations are a little north of the opening of the valley: as if the detritus had been pushed thus far, but could not be forced into the narrow valley. As we follow the valley southerly, we find remnants of lateral moraines wherever a recess exists protected by the salient sides of the valley. Towards its southern part, a wide field of many hundred acres, entirely level, is strewed over with rounded stones, 4 or 5 inches in diameter, either by glacial or aqueous action: an occurrence which I have scarcely met any where else. Large quantities of sand and some gravel are pushed southerly a little beyond the opening of this valley, into Sunderland and Amherst; but whether by glacial or aqueous agency I am uncertain: probably by both.

Between the eastern extremity of Holyoke and the primary ranges in Belchertown, is a narrow gorge where we witness moraines similar to those in Montague. In my report I have described three ponds situated in this gorge, in such a manner as to empty at both extremities. I am now satisfied that the different ponds resulted from several terminal moraines, produced by a retreating mass of ice. North of the gorge for several miles, we find extensive moraines, which might perhaps be regarded as vast lateral moraines, though I apprehend here was a blending of terminal and lateral moraines. In this group occur the singular tumuli and tortuous ridges of gravel, exhibited imperfectly in Fig. 73 of this Report.

On the east side of the gorge above described, we find moraines at a much higher level than those just described; and from this case, as well as others, I infer that the glacial action must have taken place at different levels. In other words, one mass of ice must have advanced southeasterly and have produced the more elevated moraines, while yet the lower part of the valleys were filled with ice, which adhered to the surface. If such were the case we see why it is that the moraines are so blended and irregular. I acknowledge, however, that the upper moraines may have been pushed to their present height by the expansive force of the ice, even from the bottom of the valleys; and the lowest ones have been produced by its retreat. The remarkable denudation of Mount Holyoke, however, described on page 389, of the following Report, I cannot explain without supposing the surrounding valleys filled at first with ice nearly to the top of that mountain, and then that another mass of ice, loaded with detritus, was slid over this surface, and commenced the work of furrowing out the remarkable valleys existing on its top. This would account for the parallelism preserved by those valleys; (called in Switzerland *Lapiaz or Lapiz.*) but the work must have been afterwards carried on partly by water, loaded probably by ice and detritus, as the ice gradually melted away. For such troughs (*Lapiaz*) in the Alps are found due in a measure to water. And yet, the denuding effects of ice must have continued even to the bottom of these valleys: for their sides show those peculiar striæ that can be the result only of the advance of masses of ice. In short, it seems to me that the striated and polished rocks, the *lapiaz*, or valleys of erosion, and the moraines of New England, show, that almost to the commencement of the historic period, there was a conjoint action of ice and water: And if the ice must have been 2000 or 3000 feet thick, it could not have melted away without the production of immense currents. Indeed, the term *diluvial* would probably be scarcely a misnomer, as applied to the last part of what seems to me now more appropriately termed the *glacial* period.

Through the middle of Amherst, from Mount Toby to Mount Holyoke, not less than eight miles, there extends a high and broad ridge of gravel and bowlders, interrupted, however, by two small streams and other depressions. On the west side of this ridge, lies the valley of Connecticut river: and on the east, a narrow valley separates it from the high hills of Pelham. Rocks in place sometimes rise through the gravel of this ridge and I am inclined to believe that the drift ought to be regarded as the union of two lateral moraines, (which, if I understand it, forms a medial moraine,) produced by glaciers in the two valleys above named. But this ridge is a good deal broken, and several minor ridges appear as if they might have been parts of terminal moraines. Of this description is the hill on which stands the College. But here, as in other parts of the state, it is impossible, I apprehend, so far as I can judge from the accurate description of Agassiz, to trace out such distinct moraines as exist in the Alps. Indeed, this writer says, that when he advanced beyond the valleys of the Alps, he could not find terminal moraines: and that "in open valleys and broad plains the phenomena of the moraines is completely changed from what it is in the narrow valleys of the Alps."

One of the changes to which the moraines have in some places been subject in this country, is that produced by the subsequent action of currents of water. In this way the detritus has been removed from the moraine where it was originally left, and redeposited by water; and hence the examples which I have given in this Report of a stratified and laminar arrangement of the sand and gravel of our drift. In this way, also, tumuli may have been formed out of lateral moraines by streams of water descending from the neighbouring hills: as perhaps may have been done in the formation of the tumuli in North Adams, sketched on Plate 3, and those on Figs. 15 and 19: though I doubt whether the last example was thus produced. I suspect it to be rather a part of a terminal moraine.

Moraines are abundant in the west part of Northampton, commencing at Round Hill, and in the east part of Granby, at the foot of Belchertown hills. But I have not found time to examine them with sufficient care to go into details.

Upon the whole, I think that the most striking examples of moraines in the mountainous parts of Massachusetts, occur where smaller lateral valleys intersect larger ones. I have mentioned one case of this kind in Amherst. Another good example is in Athol, a little north of the middle of the town, where the two branches of Miller's river unite. If I mistake not, several terminal moraines may be seen there, cut through by the river. The principal part of the drift appears to have been brought down the valley running north and south. Other examples occur on the east side of the principal valley in Berkshire, as we ascend Hoosac mountain through the lateral valleys that *debouch* in Lee and Dalton. Similar phenomena may be seen all along the Western Slope of Hoosac mountain, where the moraines and the detritus of moraines and the erratic blocks are exceedingly abundant.

Dr. Buckland regards the "parallel terraces" of Scotland, as "the effects of lakes produced by glaciers." In regard to similar phenomena in Massachusetts, described in this Report under the name of *terraced valleys*, I do not feel prepared to give a decided opinion. I will only refer to the terraces seen in the basin of Deerfield meadows. The most elevated of these are certainly composed almost wholly of horizontal layers of clay, deposited above the drift, which clay was subsequently carried away from the central parts of the valley, so as to leave a margin of clay. In this case no glacial agency could have been concerned, except perhaps to form the lake in which the clay was deposited. I think the terraced valleys in Westfield will be found similar to those in Deerfield. But others may have been produced by ice, whose moraines were subsequently modified by water.

To conclude: the theory of glacial action has imparted a fresh and a lively interest to the diluvial phenomena of this country. It certainly explains most of those phenomena in a satisfactory manner. It seems to me, however, that the term *Glacio-aqueous action* more accurately express this agency than the term *glacial action*: for the effects referrible to water are scarcely less than those produced by ice. I could wish that the theory gave a more satisfactory explanation of the southerly direction taken by the drift. Perhaps this is a point which can be only hypothetically solved. It may have been connected with the cause which introduced the glacial epoch. Whether this came in suddenly, as Agassiz supposes, or slowly, as Lyell maintains, we know of no cause now in operation that could have produced the change from a tropical to more than an arctic climate, and then back again to a temperate climate. Is it possible that the earth, after having assumed its present spheroidal form, and nourished successive races of animals and plants in some genial sphere, was suddenly deprived of external light and heat, and of its motion on its axis, and exposed to the severe cold of the celestial spaces (—58° Fahr.) Its waters would retreat towards the poles and become ice. Let it next be placed in its present orbit and commence its present motions: and would not the ice, as it melted, both from its expansive and centrifugal force, take a southerly direction? But I forbear: for enough of dreamy hypotheses on this subject have already had an ephemeral existence, and passed onward into the caves of oblivion.

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## *Additional Errata.*

p. 356, line 6 from top, for *most* read *not*.
p. 475, line 4 from top, for *rarely* read *nearly*.

## PART I.

# ECONOMICAL GEOLOGY

OF

## MASSACHUSETTS.

The commissions with which I have been honored by the Government, for a Survey of the Geology and Natural History of Massachusetts, have directed my attention to the following leading objects.

First, to collect, examine, and analyze, all the varieties of our soils; and to suggest means for their amendment.

Secondly, to search after, and to describe, all those varieties of marl, coal, ores, rocks, and other minerals, that are of pecuniary value.

Thirdly, to describe the most interesting features of our natural Scenery.

Fourthly, to describe the rocks of the state scientifically.

Fifthly, to collect specimens of all our soils, rocks, and minerals, for a State Collection.

Sixthly, to construct a Geological Map of the State.

Seventhly, to prepare Catalogues of the Plants and Animals found naturally within the limits of the State.

In the Reports which I have heretofore made, I have embraced all these objects to a greater or less extent. But as the facts which I have given are scattered in different reports, I propose in this report to bring them together in systematic order; and to incorporate with them other facts, which have been brought to light since my last communication to the Government; that they may have a connected view of the geological resources and the related interesting phenomena in the State. I have thought this a better course than to present a mere supplement to my former reports; which must either presuppose so much acquaintance with former reports as to make it obscure, or refer so often to facts detailed elsewhere, as to make it equally voluminous; while it would be less satisfactory than an entirely new report. But since a new Commission has recently been constituted for Botany and Zoology, com-

posed in many cases of the very gentlemen to whom I formerly resorted for help, I may now pass by these subjects, and confine my attention to our Mineralogy and Geology.

### THE GEOLOGY AND CHEMISTRY OF SOILS.

The Economical Geology of the State will first receive attention. This will embrace the two first objects of my commission as stated above. The subject of Soils—their origin and nature—analysis and amelioration—sometimes called Agricultural Geology—will first come under consideration.

#### *Origin and Nature of Soils.*

All geologists and chemists agree in regarding soils as the result of the abrasion, disintegration, and decomposition of rocks, with the addition of certain saline, vegetable, and animal substances. Ever since the deposition of rocks, various agents have been operating upon them to wear them down, to cause them to crumble or disintegrate, and often to decompose them into their proximate or ultimate principles, while they have been constantly receiving vegetable and animal substances with soluble salts. The earthy portions, however, always constitute by far the largest part; and hence, if we know the composition of the rocks whence they were derived, we shall know the earthy and metallic constituents of the soil. Now we find that nearly all the rocks which exist in large quantity, are composed chiefly of silica, alumina, lime, and oxide of iron: and these are the ingredients that are found almost invariably in soils. Magnesia is also usually present in small quantity; as is also manganese in some soils. Silica is in the largest quantity, both in the rocks and the soils; alumina next; while the other ingredients are in much smaller proportion. I ought, also, to add potassa and soda; which are very widely diffused, though not usually in large quantity. To give a numerical statement, derived from numerous analyses, such rocks as most of those in New England contain 66 per cent, of silica, 16 per cent, of alumina, 6 or 7 per cent, of potassa, 5 per cent, of oxide of iron, and of lime and magnesia a less quantity: and the composition of our soils will probably be found to correspond very nearly with these numbers, with the exception, perhaps, of the potassa which may have in a good measure disappeared by the operation of vegetation.

A large part of most soils being merely rocks reduced to minute fragments without being decomposed, will as remarked above, be of the same chemical composition as those rocks. Now in almost all cases rocks are composed mainly of silicates; viz. the silicates of alumina, lime, magnesia, iron, potassa,

soda, &c. In a region where limestone predominates, we might expect, and do sometimes find, that a considerable proportion of the soil is made up of carbonate of lime. Yet this substance is more liable to decomposition than the silicates, and often a large part of it is converted by the action of living and dead vegetable and animal matter into other combinations. Thus decomposed manures form what is called geine or rather geic acid; and this unites with lime forming a geate of lime. Geates of alumina and magnesia are formed in the same manner. Living vegetables also contain generally sulphate and phosphate of lime; and by the decomposition of these vegetables, these salts will be widely disseminated through the soils. But this subject will be better understood when I have given further details.

### *Classification of Soils.*

The above ingredients are combined in different proportions in the different rocks, so as to constitute several sorts. Hence we should expect, and in fact we find, a corresponding difference in the soils resulting from their decomposition. Indeed, with some exceptions, the geologist is able to ascertain the nature of the rock from the character of the soil that covers it. And I apprehend that it will not be difficult to point out the characteristics of the soils derived from the different rock formations of Massachusetts, so that they can be distinguished by those not familiar with practical geology. This Geological Classification is the only one which I shall attempt to give of our soils; and this seems to me all that is necessary, or useful, in addition to the common division into sandy, clayey, loamy, calcareous, &c. The following list embraces, it appears to me, all the important varieties of soil in Massachusetts.

1. Alluvium, from rivers.
   Do. peaty.
2. Diluvium, sandy and gravelly.
   Do. argillaceous.
3. Tertiary soil, argillaceous.
   Do. sandy.
4. Sandstone soil, red.
   Do. gray.
5. Graywacke soil, conglomerate.
   Do. slaty, gray.
   Do. slaty, red.
6. Clay slate soil.
7. Limestone soil, magnesian.
   Do. common.

8. Mica slate soil.
9. Talcose slate soil.
10. Gneiss soil, common.
    Do. ferruginous.
11. Granite soil.
12. Sienite soil.
13. Porphyry soil.
14. Greenstone soil.

A few paragraphs of explanation will, I trust, render these varieties of soil recognizable.

In general, if any one wishes to know where to find them, let him look at the Geological Map that accompanies this report, and he may conclude that the different soils cover those portions of the surface that are represented as occupied by the rocks from which they are derived. There is one circumstance, however, that prevents us from considering the boundaries of the rock formations as perfectly coincident with those of the soils. Diluvial action has removed nearly all the loose covering of our rocks in a southerly direction; often several miles; and more or less mingled the soils from different formations. Hence, where one formation lies north or south of another on the map, we may conclude that the detritus of the most northerly one has been swept southerly, or southeasterly, for several miles beyond the boundaries of the rock; and in few cases does the dividing line between two formations so exactly coincide with the direction of the diluvial current, that there is no overlapping and intermingling of the soils.

With common alluvial soils—the result of deposition from rivers,—every intelligent man is familiar. They are of course formed by the comminution of every kind of rock over which the stream that produces them happens to pass. These soils, I apprehend, owe their value chiefly to the fine state to which their component parts are reduced. In Massachusetts our alluvia are frequently coarse and quite siliceous.

Peat alluvium is composed principally of vegetable matter, and ought rather to be regarded as a manure than a soil. I include in it all those swamps that abound in decomposing vegetable matter, whether actually converted into peat or not.

Diluvial Soil is the most heterogeneous and wide spread of all soils, and strictly speaking it embraces nearly all our soils except alluvium: for nearly all of them have been moved and comminuted by diluvial action. But where a formation is so extensive that this diluvial agency has not transported the detritus derived from it beyond its boundaries, the soil may be regarded as belonging to that formation; and this is the case over a large part of the state: so that it will not be necessary to regard very extensive districts

of our soils as diluvium. I have not done it when it is possible to refer them to any other formation.

The most common variety of diluvial soil, and the poorest of the soils, consists of rounded pebbles and coarse sand, accumulated in situations where no existing streams could have carried them. I now also regard all those beds of clay and sand which occur in the state, except the plastic clay of the south-eastern part, as the result of the retiring diluvial waters; so that there will be an argillaceous and a sandy diluvial soil; such as occur extensively in the valley of Connecticut river, and which I formerly denominated the Newest Tertiary.

The tertiary soils are almost exactly like the two last described varieties of the diluvial, viz. argillaceous and sandy. Indeed, it is doubtful whether any character except position can distinguish them: nor is the distinction of any importance in a practical point of view. The tertiary soils occur only in a few limited districts, in Dukes, Barnstable and Plymouth counties: viz. wherever the plastic clay exists so near the surface, as to modify the superincumbent diluvial sand.

The sandstone soil is confined exclusively to the vicinity of Connecticut river. Most of the sandstone there is of a red color; some of it even a blood red; and its disintegration has produced a soil of the same aspect; so that even at a great distance, the redness is quite manifest. There is no soil that can easily be confounded with this, except some limited tracts of ferruginous gneiss soil in Worcester county, and of chocolate colored graywacke, and red compact feldspar, in the eastern part of the State. In a few towns, as in Granby, the sandstone soil is of a gray color, because the rock is gray beneath it.

The graywacke soil is confined to the eastern part of the State. Its color is mostly a deep brown; and it is capable of being made some of the best land in the State; as will be evident when I refer to Dorchester, Roxbury, Brookline, Newton, Cambridge, the Bridgewaters, Taunton, Middleborough, Dighton, Somerset, &c. for examples of its most perfect development. In some of these towns the rock is chiefly a coarse conglomerate or plum pudding stone; and as this contains more calcareous matter than the slaty varieties, and decomposes more readily, probably it furnishes the best soil found over this formation. The slaty varieties occur in Quincy, Newton, Charlestown, &c. In the southwest part of Attleborough, the slate is of a chocolate color, and this peculiar hue is imparted to the soil. The same color prevails in some other places; but not extensively enough to produce any striking patches of this variety of soil.

The group of rocks underlying this variety of soil is denominated *graywacke,* not because it has been proved to be identical with the graywacke of Eu-

rope; but because it seems analogous in composition and structure with the European rocks of that formation: and there is nothing yet discovered in regard to its position that proves its age to be different.

The tracts are very limited in Massachusetts, where well characterized argillaceous or roofing slate is fully developed: and hence we have but little genuine clay slate soil. Where it does occur, as in a few towns in Worcester and Middlesex counties, also in Bernardston, in Franklin county, it has the dark color of the slate; and is easily distiguished. It is capable of being made an excellent soil.

The limestone soil is confined to the county of Berkshire. I give it this name because it lies above limestone; not because it contains more of the salts of lime than other soils in the State. For to my surprise, I find that in general it does not. Much of it probably resulted from the disintegration of the mica and talcose slates that occur in large quantities along with the limestone in that county; and probably, also, the calcareous matter, which it did once contain, has been exhausted by cultivation. The magnesian limestone and the soil thence resulting, appeared to me more extensive in New Marlborough than in any other part of the county.

The mica slate soil, which occupies extensive regions in Massachusetts, as the Geological Map will show, is distinguished in appearance from the clay slate soil, chiefly by being of a lighter color. Yet since the two rocks pass into each other imperceptibly, so do these soils. And in the western part of Berkshire county, as well as in the mica slate region extending from Worcester to the mouth of Merrimack river, the mica slate approaches so near to argillaceous slate, that the soil above it might, without much error, be referred to the latter rock. Most of our mica slate soils are of a superior quality.

The talcose slate soil is rather limited, and not of the best quality; though it should be recollected that it occupies some of the highest parts of the State, and might at a lower level be more productive. The argillo-talcose slate soils of the Taconic range in Berkshire, are of a better quality. In appearance the mica slate and talcose slate soils can hardly be distinguished from each other; though in general the latter is of a lighter color and more sandy.

Gneiss soil occupies more surface than any other in the State: and were we to judge from its appearance, we should conclude it the poorest soil within our limits. In general, it is of a pale yellow color, and very sandy or gravelly. And, indeed, in many places it is very meagre and unproductive. But over a great part of Worcester county, for instance, it is of a very different character, being enriched probably by the potassa of the feldspar and mica in gneiss. The ferruginous gneiss soil contains so much peroxide of

iron, that in some towns, as West Brookfield, Sturbridge, Brimfield, Oakham, &c., it is of a perceptible red color when seen at a distance.

Since granite and gneiss are composed of the same ingredients, the soils which they produce will not differ. And in fact they do not in Massachusetts: so that probably there is little advantage in separating them.

Sienite differs from granite in taking hornblende into its composition, as well as being in general of a finer texture. The soil resulting from its decomposition is certainly more favorable to cultivation than that derived from common granite: as an example of which I may refer to nearly the whole of Essex county.

The compact feldspar, that forms the basis of porphyry, frequently contains an unusually large proportion of alumina, from 15 to 30 per cent. And although this is the hardest of the rocks around Boston, in many places it decomposes rapidly, and the resulting soil admits of high cultivation, as may be seen in Medford and Lynn.

The greenstone in the eastern part of the State is so intimately connected with sienite and porphyry, that the attempt to separate the soils resulting from them, is almost useless. Yet the structure of the greenstone is finer, and where it predominates, we find a good soil; as in Ipswich and Woburn. The greenstone associated with sandstone, near Connecticut river, has a more earthy aspect, and produces by decomposition a peculiar yet valuable soil, of a deep brown color, and abounding in iron. It is, however, but of limited extent.

Sir Humphrey Davy divides soils into Clayey, Loamy, Chalky, Gravelly, Sandy, Peaty or Mossy, Boggy and Heathy, and Moory: Chaptal makes a more simple division into Argillaceous, Calcareous, Siliceous and Sandy. These divisions are very convenient, and it is only for the sake of reference that I have adopted in their stead the geological classification described above.

### *System pursued in collecting Soils.*

In executing that part of my commission which relates to the analysis of soils, I found it very difficult to decide upon the best plan for collecting them. My object was not to examine the soils of particular farms, or towns; but rather to point out the composition and character of the different classes of soils in the State. I therefore concluded to visit the different rock formations; and where I found the soils above them well characterized, to select specimens, in sufficient numbers, and over a sufficiently wide extent, to afford a fair representation of the different sorts of soils. Whatever might be found to be the characters of these selected specimens, from any particular

formation, I thought might be regarded as the characters of the soil in general over that formation; and to determine its extent, it would be necessary only to consult the Geological Map, with the statements in mind that have been made respecting diluvial action. And it is chiefly this consideration that led me to prefer the geological classification of soils. On this plan it seemed to me unnecessary to designate the particular farms from which the specimens were obtained.—I took care, however, in all cases, except those hereafter mentioned, to select my specimens from a cultivated ploughed field; about half way between the subsoil and the surface; and in a spot where the vegetable fibres had nearly disappeared by decomposition. I avoided, also, in general, the vicinity of buildings; especially barns: as I did also those fields where the soil had become very factitious by high cultivation; or where it was very sterile through neglect of culture. I endeavored to select spots where a medium state of cultivation existed; because I conceived that these would present the fairest average examples of the capabilities of our soils. And as most of the specimens were collected towards the close of summer, I could judge from the crops growing upon the fields, where the soil was in a medium state of cultivation. In a few cases I have purposely or accidentally taken specimens either from very poor or very rich spots; but such examples will be pointed out, when I come to give details. Roots, undecomposed manure, and large pebbles, were as much as possible avoided: and before proceeding to an analysis, I separated all the roots and pebbles larger than a quarter of an inch, with a course sieve. For although such matters generally exert some, and often a great influence upon the cultivation, yet it seems to me that their chemical examination can add little or nothing to what experience has already taught on this subject.

The soils were collected in tin canisters, which were labeled on the spot. Afterwards the specimens were spread out and exposed for several days to a warm sun and dry air, so as to expel all the moisture which could be driven off by natural evaporation. They were then returned to the canisters, and a portion taken for the various analytical processes which were adopted. After this, the residue was put into white glass bottles, which were sealed, numbered, and deposited in the State collection, along with other substances, such as marls, clay, quick much marsh mud, ochre, &c. This arrangement makes the specimens easy to be examined by the eye, without the danger of waste by uncorking the bottles.

### *Leading Objects of the Analysis of Soils.*

The views that have been given as to the origin and nature of soils will enable us to make a threefold classification of their constituents. First, their

earthy and metallic ingredients, which are chiefly silicates: Secondly, the acids, alkalies, and salts, which exist originally in them, or are introduced by cultivation: and thirdly, the water and organic matter which they contain. The latter constitutes the principal nourishment of plants, derived from the soil; while the salts are necessary to prepare that nourishment to be taken up and assimilated by their delicate vessels. The earth serves as a basis of support for the plant, as a receptacle for the nourishment, and probably also, in connection with the roots, as a galvanic combination, for the development of those electrical agencies by which the food of plants is taken up and converted into vegetable matter.

By almost any method of analysis that can be adopted, the three leading objects above specified will be more or less combined. But as some of these methods have a chief reference to one of these points, and others to other points, it will be practicable, in the first place, to confine our attention mostly to the earthy constituents of soils; and in the second place, to examine more particularly their salts and organic matter.

### *Analysis of Soils by Sir Humphrey Davy's Method.*

The method of analyzing soils proposed by the distinguished English chemist, Sir Humphrey Davy, in his Agricultural Chemistry, has been almost universally regarded as the best that has been invented. It consists in first driving off the water of absorption by a heat of 300°: Secondly, in boiling the soil in water, and suffering the coarser parts to settle, which are regarded as silica; while the finer, or aluminous portion, is suspended in the water, and is poured off: Thirdly, in determining by muriatic acid, the amount of carbonate of lime, if any be present: Fourthly, in burning off the organic matter of the finer part of the soil: Fifthly, in boiling the remainder in sulphuric acid, in order to dissolve the alumina and oxide of iron: Sixthly, in ascertaining the amount of soluble salts in the water employed for lixivation. The French Chemist, Chaptal, proposes essentially the same plan, though he renders it much more simple, by omitting the most difficult part; that is, the solution of the alumina and iron by sulphuric acid. The high reputation of Davy's rules led me to attempt their application to nearly half the soils which I had collected in Massachusetts: and the results are contained in the Table which follows.

Before presenting any analytical results, however, I wish to state the circumstances under which this part of the survey has been conducted. In some of the larger States of the Union, where geological surveys have been commenced, one or more chemists are constantly employed in the laboratory.

No such course was adopted in Massachusetts: but the surveyor was directed, in general terms, to make an analysis of the soils, in his commission for a re-examination of the State. The question then arose in my mind, whether it would be possible, while carrying forward the other parts of the survey, to make a sufficient number of analytical investigations to be of much use. It was obvious that the time which I could devote to the subject, would not permit me to perform very numerous analyses with the extreme care and multiplied repetitions which the precision of modern science demands, in order to employ the results in settling the atomic constitution of bodies. Yet it occurred to me, that the objects of the Government might be in a good measure accomplished, if the results were not of the extremely accurate character above described. By a variety of means, some of which are described in the subjoined note,* and by the most laborious and devoted attention to the subject, I have been able to present a great number of results, which I trust will be found sufficiently accurate for the purposes I had in view. I do not mean that the processes were not conducted with care; and that I did not repeat them. Very many of them have been repeated again and again; especially whenever there was reason to suspect any material error in the results. Nor do I mean to say, that none of these results are sufficiently accurate to form the basis of scientific reasoning. As to that point, scientific men can judge when they examine my analyses: But I do not offer my conclusions for such a purpose: and wish, as an act of justice to myself, to have it understood, that the standard by which my analyses ought to be tried, is that of their practical value in an economical, not in a scientific point of view.

The following Table exhibits the results of the analysis of 61 soils, selected from the different formations in the State. For convenience, they are all

* The arrangement by which I was enabled most successfully to facilitate the process of analysis, consisted in providing means for carrying on ten similiar processes together. I made ten compartments upon a table, each provided with apparatus for filtering and precipitation. Ten flasks and ten evaporating dishes were also numbered, as well as ten common crucibles, with a circular piece of sheet iron, pierced with ten holes, and numbered to receive the crucibles. An oven of sheet zinc, with double sides, was likewise fitted up so as to receive ten filters, and to admit a thermometer. The sand bath was also made large enough to admit the ten flasks. By this arrangement, all the important processes in the analysis of soils, by the methods of Sir H. Davy and Dr. Dana, except weighing, could be conducted together, and almost as rapidly as if only one had been carried on. Even the weighing was in this way much facilitated, as any one can easily conceive. I applied also, so far as it was possible, the same method in conducting analyses in a more accurate manner. I supplied myself with four or five platinum and silver crucibles, which being charged, their contents were either fused together in a charcoal fire, or in succession over a spirit lamp. This process was repeated until ten substances were obtained in a state of fusion. Afterwards the processes were conducted as above described; except that the ignition of the results was performed over the spirit lamp. It is easy to see how by this arrangement a great saving of time was made.

I would not forget to mention also, my indebtedness to the faithfulness and perseverance of my chemical assistant, Mr. Abraham Jenkins, Jr. of Barre.

reduced to the same standard, viz: 100 grains; and the small loss, which inevitably attends this mode of analysis, has been apportioned among the several ingredients.

| No. | NAME AND LOCALITY OF SOIL. | Water of Absorption. | Organic Matter | Siliceous Deposite from Water. | Aluminous Deposite from Water. | Salts soluble in Water. | Composition of the Aluminous Deposite. Silica. | Alumina. | Oxide of Iron |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil; Deerfield. | 3.0 | 5.5 | 29.8 | 61.7 | | 55.2 | 3.5 | 3.0 |
| 2 | do Northampton. | 3.4 | 5.1 | 32.8 | 58.5 | 0.20 | 51.7 | 3.4 | 3.4 |
| 3 | do Deerfield. | 2.0 | 4.5 | 43.2 | 50.3 | | 44.1 | 3.7 | 2.5 |
| 4 | do Northampton. | 3.0 | 3.0 | 74.8 | 19.0 | 0.15 | 16.2 | 1.3 | 1.5 |
| 5 | do Northfield. | 2 7 | 4.2 | 43.9 | 49.2 | | 44.0 | 2.4 | 2.8 |
| 6 | do Northampton. | 2.1 | 3.2 | 40.0 | 54.7 | | 51.0 | 1.7 | 2.0 |
| 7 | do West Springfield. | 1.3 | 5.0 | 67.9 | 25.4 | 0.20 | 21.6 | 1.2 | 2.6 |
| 8 | do Stockbridge. | 1.9 | 4.9 | 83.5 | 9.7 | | 7.4 | 1·3 | 1.0 |
| 9 | do Hadley. | 4.4 | 6.6 | 45.6 | 43.0 | 0.20 | 39.4 | 1.6 | 2.0 |
| 10 | do Sheffield. | 2.2 | 5.5 | 62.1 | 30.0 | 0.20 | 23.9 | 3.0 | 3·1 |
| 13 | Tertiary Soil, Argillaceous; Springfield. | 3.3 | 10.0 | 47.8 | 38.7 | 0.16 | 32.7 | 3.5 | 2.5 |
| 16 | do do Barnstable. | 2.6 | 9.4 | 47.2 | 40.8 | 0.05 | 29.8 | 6.7 | 4.3 |
| 18 | do Sandy; Wareham. | 1.2 | 0.4 | 98.4 | 0.0 | | | | |
| 19 | do do Springfield. | 1.7 | 2.7 | 92.8 | 4.8 | | 2.4 | 1.3 | 1.1 |
| 20 | do do Barnstable. | 1.0 | 0.2 | 98.3 | 0.5 | | | | |
| 21 | do do Gloucester, (Squam.) | 0.15 | 0.0 | 99.6 | 0.0 | 0.20 | | | |
| 23 | Sandstone Soil, red; Longmeadow. | 2.4 | 4.4 | 79.0 | 14.0 | 0.20 | 10.6 | 1.3 | 2.1 |
| 25 | do do West Springfield. | 2.6 | 6.1 | 50.5 | 40.4 | 0.38 | 32.6 | 4.2 | 3.6 |
| 26 | do grey; Granby. | 2.8 | 3.9 | 37.3 | 55.9 | 0.13 | 48.6 | 2.6 | 4.7 |
| 27 | Graywacke Soil, Conglomerate; Dorchester. | 3.0 | 7.8 | 61-7 | 27.5 | | 19.3 | 4.7 | 3.5 |
| 30 | do do Walpole. | 2.2 | 7.6 | 56.0 | 34.1 | 0.10 | 28.5 | 3.1 | 2.5 |
| 31 | do do Dighton. | 1.6 | 5.2 | 59.3 | 33.8 | 0.10 | | | |
| 32 | do Slaty; Middleborough. | 1.7 | 6.0 | 69.2 | 23.0 | 0.10 | 17.0 | 2.2 | 3.8 |
| 35 | do do Watertown. | 4 1 | 9.1 | 45.6 | 41.0 | 0.20 | 31.9 | 4.1 | 5.0 |
| 36 | do do Halifax. | 1.5 | 5.5 | 82.6 | 10.3 | 0.14 | 6.9 | 2.3 | 1.1 |
| 38 | do do Taunton | 2.0 | 6.0 | 76.4 | 15.5 | 0.10 | 11.1 | 2.8 | 1.6 |
| 40 | do do, red; Attleboro,' S. W. part. | 3.2 | 9.7 | 43.0 | 44.0 | 0.12 | 27.5 | 8.0 | 8.5 |
| 41 | Argillaceous Slate Soil; Lancaster. | 3.0 | 9.5 | 59.3 | 28.1 | 0.09 | 23.1 | 3.1 | 1.9 |
| 43 | do do Townsend. | 3.5 | 11.5 | 70.5 | 14.2 | 0.32 | 7.2 | 4.5 | 2.5 |
| 44 | Limestone Soil, Magnesian; New Marlborough. | 1.9 | 5.8 | 67.6 | 24.6 | 0.12 | 16.6 | 4.0 | 4.0 |
| 45 | do common; Lanesborough. | 2.5 | 7.5 | 61.3 | 28.5 | 0.20 | 17.0 | 4.5 | 7.0 |
| 47 | do do North Adams. | 1.4 | 5.1 | 73.9 | 19.5 | 0.14 | 13.5 | 3.5 | 2.5 |
| 50 | do do Pitsfield. | 4.0 | 9.0 | 63.7 | 23.2 | 0.10 | 16.2 | 4.0 | 3.0 |
| 51 | do do Sheffield. | 3.9 | 7.2 | 67.7 | 20.9 | 0.32 | 11.9 | 5.0 | 4.0 |
| 54 | Mica Slate Soil; Webster. | 2.8 | 10.4 | 51.2 | 35.5 | 0.14 | 27.9 | 5.4 | 2.2 |
| 56 | do Stockbridge mountain. | 3.1 | 7.4 | 59.7 | 29.7 | 0.10 | 19.7 | 4.7 | 5.3 |
| 58 | do Bradford. | 3.0 | 10.4 | 44.0 | 42.3 | 0.25 | 32.3 | 5.8 | 4.2 |
| 59 | do West Newbury. | 3.0 | 7.6 | 65.2 | 24.1 | 0.10 | 16.2 | 5.1 | 2.8 |
| 60 | do Methuen. | 1.4 | 4.0 | 83.0 | 11.6 | | 6.4 | 1.0 | 4.2 |
| 63 | do Conway. | 1.4 | 6.3 | 67.7 | 24.5 | 0.10 | 18.3 | 4.3 | 1.9 |
| 65 | Talcose Slate; Charlemont. | 2.5 | 6.0 | 72.0 | 19.4 | 0.08 | 12.7 | 1.9 | 4.8 |
| 67 | Talco-micaceous Slate Soil; Hancock. | 2.8 | 9.7 | 44.8 | 42.7 | | 30.4 | 7.6 | 4.7 |
| 70 | Gneiss Soil; Bolton. | 2.8 | 7.3 | 63.5 | 26.2 | 0.25 | 22.2 | 2.3 | 1.7 |
| 71 | do Uxbridge. | 2.5 | 7.0 | 37.8 | 52.5 | 0.19 | 44.8 | 4.3 | 3.4 |
| 77 | do Rutland. | 3.8 | 10.2 | 58.7 | 27.0 | 0.26 | 21.0 | 3.5 | 2 5 |
| 79 | do Royalston. | 4.0 | 9.0 | 67.6 | 19.3 | 0.14 | 14.9 | 3.2 | 1.2 |
| 89 | do Grafton. | 3.0 | 7.7 | 40.1 | 49.0 | 0.20 | 38.9 | 6.7 | 3 4 |
| 90 | do Brimfield | 2.1 | 6.9 | 70.9 | 20.0 | 0.10 | 15.9 | 2.9 | 1.2 |
| 93 | do Becket. | 4.0 | 9.0 | 64.6 | 22.0 | 0.40 | 16.6 | 3 4 | 2.0 |
| 96 | do Sturbridge. | 1.8 | 5.7 | 77.1 | 15.2 | 0.22 | 11.3 | 2.3 | 1.6 |
| 104 | Granite Soil; Andover. | 3.3 | 9.5 | 54.4 | 32.6 | 0.20 | 26.9 | 3.9 | 1.8 |
| 106 | Sienite Soil; Marblehead. | 3.7 | 8.9 | 61.5 | 25.8 | 0.10 | 20.0 | 2.3 | 3.5 |
| 108 | do Gloucester. | 1.7 | 4.8 | 80.0 | 13.4 | 0.13 | 9.6 | 2.1 | 1 7 |
| 109 | do Lexington. | 3.7 | 10.0 | 46.7 | 39.4 | 0.16 | 34.0 | 3.0 | 2.4 |
| 111 | do Newbury. | 3.5 | 7.5 | 60.1 | 28.8 | 0.12 | 22.2 | 4.4 | 2.2 |
| 112 | do Dedham. | 4.3 | 9.9 | 46.3 | 39.3 | 0.17 | 31.4 | 5.1 | 2.8 |
| 117 | do Marshfield. | 2.0 | 5.2 | 68.7 | 24.0 | 0.11 | 19.2 | 2.7 | 2.1 |
| 120 | Porphyry Soil; Medford. | 4.1 | 10.6 | 51.9 | 33.2 | 0.15 | 27.7 | 3.5 | 2.0 |
| 122 | do Lynn. | 4.0 | 8.5 | 46.4 | 40.8 | 0.30 | 34.6 | 3.7 | 2 5 |
| 124 | Greenstone Soil; Woburn. | 4.0 | 10.3 | 46.7 | 38.9 | 0.15 | 33.7 | 2.3 | 2.9 |
| 125 | do Deerfield. | 2.0 | 7.0 | 32.7 | 58.2 | 0.10 | 30.5 | 3.3 | 4.4 |

*Explanation of the preceding Table with remarks.*

The numbers in the first column of the preceding table, denote the specimens of the soils deposited in the State collection: and the second column points out the name and locality.

However thoroughly soils are dried in the sun, a quantity of water still adheres to them, which cannot be entirely driven off, until they are heated to nearly 300° of Fahrenheit's thermometer; or to the point where paper begins to turn brown. This was the way in which the numbers in the third column were obtained, by heating 100 grains to that point and noting the loss of weight. Highly siliceous soils retain but very little of this water of absorption, while from highly aluminous ones, it is not all driven off by heating to 300°. The power of soils to retain water, however, depends much more upon the quantity and character of the organic matter which they contain, than upon their mineral composition, as I shall endeavor to show hereafter.

After driving off the water of absorption, the soil was heated to redness, and continued in that state until every thing combustible was burnt off. The loss of weight showed the quantity of organic matter; and thus the fourth column was formed.

The fourth column in the above table presents one fact worthy of notice. It seems that our alluvial soils, although deservedly celebrated, contain less of organic matter than almost any other in the State. The principles above suggested explain their fertility in consistency with this fact: but it shows us, if I mistake not, that such soils, if not constantly supplied with manures, either by the overflowing of rivers, or by the farmer, will be sooner exhausted than almost any others.

The numbers in the fifth and sixth columns were obtained in the following manner. One hundred grains of the soil were boiled a short time in a glass flask in water, and after cooling, this was agitated until the soil was all diffused through the water. As soon as the agitation of the water had ceased, it was poured off along with the finer parts of the soil that did not settle at once. The portion that remained usually consisted of siliceous sand, while that which was left suspended in the water, was much more aluminous, and constituted the finest and most important part of the soil. In the present instance, this deposite is in larger proportion than is usual in analysis, because it was poured off immediately after the agitation had ceased, under an impression that by waiting two or three minutes, as is usual, other and more important substances than silica may settle to the bottom of the vessel. In deed, I found this to be the case in some instances when the light matter was

poured off immediately. Thus, the red sandstone soil, No 23, from Longmeadow, gave only 14 grains of aluminous matter, and 79 grains of siliceous. By digestion in acid, the 14 grains yielded only 1.3 gr. of alumina and 2.1 gr. oxide of iron. But by treating the 79 grains of siliceous matter in the same way, it produced 7.5 grains of alumina and 4 grains peroxide of iron. Such cases teach us that this mechanical separation of the siliceous and aluminous matter is not a little uncertain: although in general it must be confessed, that when the lighter part was poured off immediately, the remainder was chiefly siliceous sand.

It is not the object of this process however, to show us the quantity of silica and alumina in a soil: but rather the amount of finely divided matter. For the best soils are found, in general, to abound in such matter: although it may become excessive, rendering the soil impervious to air and moisture. This is a principal defect in highly argillaceous soils. But from the preceding table it appears, in my opinion, that the soils in Massachusetts are in general too coarse rather than too fine. Being derived chiefly from primitive rocks, they resist comminution and decomposition more than the secondary rocks. I am satisfied that the principal excellence of our alluvial soils depends more upon their finely divided state than any thing else: for, as I have already in part shown, and shall show farther in the sequel, they must yield in value in some important respects, to our upland soils. And even as to their fineness, they are much coarser than many of the rich alluvia of the Western States; though it may be doubted whether for most crops they are on this account the less valuable.

The term salt, in chemistry, has a much more extended meaning than in popular language. Thus common limestone (carbonate of lime) and gypsum (sulphate of lime) are properly denominated salts, as is also phosphate of lime and chloride of calcium (muriate of lime). All compounds of any acid with lime, magnesia, alumina, potassa, soda, &c. or of chlorine with their metallic bases are salts: and some of these are soluble and some insoluble in water. If any of the former exist in soils therefore, they will be dissolved, if the soil be boiled in water. And if afterwards this water be evaporated, the salt can be obtained in a dry state and weighed. This is the way in which column seventh was filled. Tests were also applied to the solutions, in order to ascertain the nature of these salts. Hydrocyanate of potassa, infusion of nutgalls, the chlorides of calcium and magnesium, and the carbonate of ammonia and phosphote of soda gave no precipitate in any instance. Hence I infer the absence of iron and the salts of magnesia. But nitrate of silver, baryta water, nitrate and acetate of baryta, and oxalate of ammonia, gave precipitates more or less abundant in every instance in which I tried them. I hence infer the presence of a sulphate, probably the sulphate of lime, in all

the soils of Massachusetts that I have examined, and I have no doubt but it exists in every one of our soils. The quantity given in the table, is probably much less than the truth, for the sulphate of lime is but slightly soluble in water, and the quantity of water which I employed, was too small to dissolve all that exists in 100 grains; or rather 200 grains, which was the quantity usually boiled. It was chiefly to ascertain the fact of its existence that the experiments were performed; since I had adopted a better method for ascertaining its quantity. This salt exists, also, probably in nearly all the springs, rivers, and ponds in the State. The great importance of gypsum, in the process of vegetation, furnishes a reason for its universal diffusion.

The remaining columns of the Table exhibit the composition of the aluminous deposite in the sixth column. That deposite was boiled two or three hours in sulphuric, or hydrochloric acid, and the alumina and iron were precipitated together by carbonate of ammonia, and afterwards separated by hydrate of potassa. The portion remaining undissolved by the acid, was considered as silica.

### *Insufficiency of this mode of Analysis.*

I might easily have proceeded farther with these analyses: but had I at the commencement the same opinion of the insufficiency of Davy's method, as I now have, I should not have proceeded even so far. So far as this method is mechanical, it is of value; since it enables any one, not skilled in the manipulations of the laboratory, to ascertain whether a soil is coarse, or in a finely divided state. But the chemistry of this method is very bad. In the first place, it does not profess to determine the amount of silica, alumina, iron, &c. in the entire soil, but only in its finely divided portion. Now I have already mentioned a case, in which the siliceous residuum (of No. 23.) yielded almost as large a per cent. of alumina and oxide of iron as the aluminous portion. And I shall soon mention numerous examples, in which accurate analysis of the whole soil shows a much larger per cent. of these ingredients than this method discovers. In the second place, this method does by no means give the relative proportion of the ingredients in a soil, especially of the silica and alumina; because the latter is soluble with difficulty in sulphuric acid. Being desirous of ascertaining what proportion of the alumina could be extracted by the direct action of acids, I selected seven of the soils given in the preceding table, and subjected the aluminous deposite, obtained in the manner that has been described, to thorough analysis by fusion with soda, in platinum crucibles. The results may be seen in the following Table.

| No. | Aluminous Deposite. | Alumina by Acids. | Alumina by Alkali. | Silica by Acids. | Silica by Alkali. | Alumina per cent. | |
|---|---|---|---|---|---|---|---|
| 2 | 58.5 | 3.4 | 17.6 | 51.0 | 37.5 | 30.1 | 30.9 Mean. |
| 40 | 44.0 | 8.0 | 11.8 | 27.5 | 23.7 | 26.8 | |
| 41 | 28.1 | 3.1 | 9.4 | 23.1 | 16.8 | 33.6 | |
| 47 | 19.5 | 3.5 | 6.3 | 13.5 | 10.7 | 32.3 | |
| 58 | 42.3 | 5.8 | 12.2 | 32.3 | 25.9 | 28.8 | |
| 89 | 49.0 | 6.7 | 14.9 | 38.9 | 30.7 | 30.4 | |
| 112 | 39.3 | 5.1 | 13.0 | 31.3 | 23.0 | 34.3 | |

The number of the soil in the state collection* is given in the first column of the above table: the amount of the aluminous deposite in the second; the alumina by boiling in acid, as given in the first table, in the third column; the alumina by fusion with carbonate of soda in the fourth column: the silica, after the action of acids, in the fifth: the silica by alkali in the sixth: and the per cent. of alumina by the same process in the last.

A mere glance at these results, if they are not very erroneous, shows us how extremely deficient are Davy's rules in this particular. It is true that a repetition of his process, with fresh sulphuric acid, would dissolve more alumina; and in this way a gradual approximation might be obtained towards the truth: but such repetitions would prove more laborious than the process by fusion with alkali, and thus defeat the very object this distinguished chemist had in view, viz. so to simplify the analysis of soils, that it might be performed by intelligent farmers, though not familiar with chemical manipulation.

But in the third place, I have been brought to the conclusion, that even if these rules should give accurately the proportion of the ingredients, they would be of little importance; because the fertility of soils depends but very little upon the proportion of their earthy ingredients: in other words, these may vary greatly, without affecting the fertility. Partly to ascertain how far this principle is true, and partly to determine more accurately what are the earthy constituents of the soils of Massachusetts, I have made several analyses of the different geological varieties by fusion with an alkali; the only method which can at all satisfy the chemist. In the first example no attempt was made to determine the presence or amount of lime and magnesia. 100 grains of a diluvial argillaceous soil from Plymouth contain,

* There are two series of numbers in the State Collection both commencing with unity. One series is confined entirely to those specimens that are contained in glass bottles, which amount to 227. The other series extends to more than 2500. To distinguish between the two series, whenever they are referred to, I shall annex the letter *b*, to those of the first series, except the soils, which amount to 152, and the marls, clays, marly clays, and muck sands, where it seems unnecessary.

| | |
|---|---|
| Water of Absorption. | 2.7 |
| Organic Matter. | 6.0 |
| Oxide of Iron. | 6.5 |
| Salts Soluble in Water. | 0.4 |
| Alumina. | 19.2 |
| Silica. | 65.2 |
| | 100.0 |

In the following examples, I directed my attention to a determination of the amount of silica, alumina, lime, and magnesia, in the entire soil; having previously driven off the water and organic matter by heat. The salts of lime were obtained by another process, which will be explained farther on; and are added here for the sake of giving a complete view of the composition of the soils. It will be seen that I have added, for the sake of comparison, four examples of some of the richest soils in Illinois and Ohio. For convenience, the results are reduced to a centessimal standard: although only 15 grains were usually employed in the analysis.

| NO. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Peroxide of Iron. | Carbonate of Lime. | Sulphate of Lime. | Phospate of Lime. | Lime. | Magnesia. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil, Deerfield. | 2.0 | 7.0 | 55.50 | 22.06 | 5.11 | | 2.00 | 0.90 | 2.18 | 2.00 | 1.23 |
| 18 | Diluvial Sand, Wareham. | 1.4 | 1.2 | 84.68 | 7.76 | 1.89 | | 0.40 | 0.40 | 2.32 | | |
| 23 | Red Sandstone Soil, L. Meadow | 4.2 | 3.6 | 65.45 | 16.45 | 5.07 | | 3.20 | 0.69 | 0.74 | 0.25 | 0.44 |
| 28 | Graywacke Soil, Roxbury. | 2.6 | 8.4 | 63.68 | 17.37 | 3.65 | | 2.30 | 1.46 | | 0.48 | 0.12 |
| 41 | Argil. Slate Soil, Lancaster. | 7.4 | 7.4 | 57.87 | 16.06 | 4.70 | | 4.69 | 0.10 | 0.59 | 0.44 | 0.04 |
| 46 | Limestone Soil, G. Barrington. | 2.0 | 6.0 | 69.92 | 12.22 | 5.03 | | 1.70 | 0.50 | 1.14 | 0.76 | 0.73 |
| 59 | Mica Slate Soil, W. Newbury. | 3.8 | 5.8 | 67.49 | 11.87 | 3.80 | | 3.50 | 1.00 | 1.09 | 1.08 | 0.57 |
| 64 | Talcose Slate Soil, Chester. | 2.6 | 9.6 | 68.01 | 14.10 | 2.57 | | 3.10 | 1.00 | | 2.82 | 1.20 |
| 81 | Gneiss Soil, Petersham. | 5.6 | 7.4 | 60.85 | 18.77 | 3.22 | | 2.40 | 0.40 | | 1.14 | 0.22 |
| 103 | Granite Soil, Duxbury. | 2.4 | 5.2 | 74.77 | 12.57 | 3.10 | | 0.86 | 0.70 | 0.11 | 0.67 | 0.28 |
| 109 | Sienite Soil, Lexington. | 4.0 | 9.8 | 65.00 | 13.11 | 4.00 | | 2.60 | 0.60 | | 0.52 | 0.37 |
| 120 | Porphyry Soil, Medford. | 2.8 | 12.4 | 59.78 | 16.38 | 3.54 | | 2.60 | 0.80 | 0.81 | 0.80 | 0.09 |
| 125 | Greenstone Soil, Deerfield. | 2.0 | 6.2 | 65.39 | 16.35 | 6.05 | 2.00 | 0.10 | 0.30 | 0.63 | 0.91 | 0.07 |
| 198 | Rushville, Illinois. | 6.3 | 9.9 | 63.35 | 15.60 | 5.57 | 1.50 | 3.40 | 0.60 | | 0.68 | |
| 199 | Sangamon Co. do. | 6.3 | 10.5 | 66.71 | 8.28 | 4.42 | 1.39 | 1.20 | 0.40 | | 0.56 | 0.33 |
| 200 | Lazelle Co. do. | 9.5 | 21.4 | 47.09 | 9.87 | 5.38 | 3.30 | 1.40 | 0.40 | | 1.08 | 0.58 |
| 201 | Sciota Valley, Ohio. | 5.3 | 11.2 | 62.64 | 9.18 | 5.40 | 2.80 | 2.10 | 0.90 | | trace | 0.48 |

The preceding Table hardly needs explanation: except to remark, that the column headed Lime, contains the excess of that substance, found by the process with alkali in some specimens, above the amount contained in the carbonate, sulphate, and phosphate. This excess probably existed in the soil either as a silicate or a geate.

For the sake of a more extensive comparison, I shall here quote a few analyses of soils that have been distinguished for their fertility. Most of them are European.

In the Second Report of Mr. Colman on the Agriculture of Massachusetts, Dr. S. L. Dana has given the analysis of a soil from Chelmsford, on the Merrimack River, which has produced a large crop of wheat for 20 years with only one failure. 100 parts contain

| | |
|---|---|
| Soluble Geine, | 3.9228 |
| Insoluble Geine, | 2.6142 |
| Sulphate of Lime, | .7060 |
| Phosphate of Lime, | .9082 |
| Silicates (Silica, alumina, iron, &c.) | 91.8485 |

No trace of carbonate of lime or of alkaline salts could be discovered.

In his third annual report on the geology of Maine, Dr. C. T. Jackson has given the following analysis of a soil from that State, which has produced 48 bushels of wheat per acre.

| | |
|---|---|
| Water, | 5.0 |
| Vegetable Matter, | 17.5 |
| Silica, | 54.2 |
| Alumina, | 10.6 |
| Sub Phosphate of Alumina, | 3.0 |
| Peroxide of Iron, | 7.0 |
| Oxide of Manganese, | 1.0 |
| Carbonate of Lime, | 1.5 |
| | 99.8 |

An excellent wheat soil from the County of Middlesex in England, was analyzed by Sir Humphry Davy, and gave in 100 parts,

| | |
|---|---|
| Siliceous Sand, | 60 |
| Finely divided matter, | 40 |

100 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 28 |
| Silica, | 32 |
| Alumina, | 29 |
| Organic Matter and Water, | 11 |

A very productive soil from the County of Somerset, gave

| | |
|---|---|
| Siliceous Sand, | 89 |
| Finely divided Matter, | 11 |

432 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 360 |
| Alumina, | 25 |
| Silica, | 20 |
| Oxide of Iron, | 8 |
| Organic and Saline Matter, | 19 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | |
|---|---|---|---|
| Ashes of wheat, | 48 Silica, | 37 Lime. | 15 Alumina. |
| " of oats, | 68 " | 26 " | 6 " |
| " of barley, | 69 " | 16 " | 15 " |
| " of rye, | 63 " | 21 " | 16 " |
| " of potatoes, | 4 " | 66 " | 30 " |
| " of red clover, | 37 " | 33 " | 30 " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an alumnious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

*Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

*Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | | |
|---|---|---|---|---|
| " | 80 | Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " | 186 | do Sandisfield, | 2.80 | " |
| " | 113 | Sienite Soil, Wrentham, | 0.40 | " |
| " | 125 | Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

### *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

tives; five copies to be deposited in the Library of the State: and that the remaining copies be distributed as His Excellency the Governor may direct.'

In the early part of 1833, a full Report was presented, and the Legislature on the 25th of February adopted the following very liberal Resolves:

'*Resolved*, that His Excellency the Governor, be, and hereby is authorized to cause twelve hundred copies of the Report on the Geological Survey of the Commonwealth; including that part of the Report already made, as well as the part hereafter to be made, with the drawings which shall accompany said Report, to be published in such way and manner as he shall deem proper and expedient; and he is authorized with the advice and consent of Council, to draw his warrant upon the Treasurer of the Commonwealth for such sum, or sums, as may be necessary to carry this resolve into full effect.'

'*Resolved*, that the said twelve hundred copies, when published, shall be delivered to the Secretary of the Commonwealth, to be distributed in the following manner, viz: twelve copies to the Governor; six copies to the Lieut Governor; one copy to each member of the Council, Senate and House of Representatives; one copy each to the Secretary, Treasurer, and to each of the Clerks and Chaplains of the two Houses; one copy to each town in the Commonwealth; five copies to be deposited in the Library of the State; two copies each to Harvard, Amherst and Williams Colleges; one copy each to the Theological Seminaries at Andover and Newton; one copy to each incorporated Academy in the Commonwealth; one copy each to the Boston and Salem Atheneums; one copy to the American Academy of Arts and Sciences: one copy to the Antiquarian Society at Worcester; one copy to the Massachusetts Historical Society; one copy to the Boston Society of Nataral History; twenty copies to the Geological Surveyor; and one copy to each person who shall have aided him in preparing the Catalogues appended to the Report; two copies to the Library of the United States; one copy to the Executive of each State in the Union, and the remaining copies to be disposed of in such a manner as His Excellency the Governor shall direct.'

On the 19th of February 1834, the following Resolve was adopted by the Legislature:

'*Resolved*, that his Excellency the Governor with the advice of the Council, be authorized to cause to be printed, under the superintendence of the Geological Surveyor, a new edition of Professor Hitchcock's Report on the Geology of this Commonwealth, and the Atlas accompanying it, with such alterations and additions as may be proposed by the Professor, and approved by the Executive; and that a warrant be drawn on the Treasurer for such sum as may be necessary to defray the expense thereof: provided that the whole expenditure shall not exceed the sum of two dollars and sixty cents for each copy.'

'*Resolved*, that the said five hundred copies, when published, shall be delivered to the Secretary of the Commonwealth, and be distributed in the following manner, viz.

Twelve copies to the Governor; ten copies to the Surveyor; one copy to each of the Chaplains of the Senate and House of Representatives; one copy to each incorporated Lyceum and Atheneum in this Commonwealth; two copies each to the Berkshire Medical Institution, and the Massachusetts Medical College; one copy to each member of the Council, Senate, and House of Representatives, who was not a member of either of those branches of the government for the last year; one copy to each of the permanent Clerks in the office of the Secretary of State, Treasurer, and Adjutant General, two copies to the Pilgrim Society at Plymouth; and the remaining copies to be disposed of in such a manner as the Legislature may direct.'

On the 12th of April 1837, the Governor and Council were authorized and requested to appoint some suitable person or persons to make a further and thorough geological, mineralogical, botanical and zoological survey of this Commonwealth, under his direction, particularly in reference to the discovery of coal, marl, and ores, and an analysis of the various soils of the State, relative to an agricultural benefit.

A Report of 139 pages on the Economical part of the Re-survey was made in the winter of 1838, and printed without any special order. In December 1839 the Final Report was presented, and the Governor was authorized to procure the publication of 1500 copies by a Resolve passed April 9th 1839, which were to be distributed as follows.

*Resolved*, That the said copies, when published, be delivered to the Secretary of the Commonwealth, to be distributed in the following manner: twelve copies to the Governor; six copies to the Lieut. Governor; one copy to each member of the Council, Senate, and House of Representatives; one copy each to the Secretary, Treasurer, and to each Clerk and Chaplain of the two Houses; one copy to the Secretary and one to each member of the board of Education; twenty copies to the Geological Surveyor, and ten to each Commissioner appointed under the resolve of April 12th, 1837; five copies to be deposited in the library of the State; one copy to each town in the Commonwealth; two copies each, to Harvard, Amherst, and Williams colleges; one copy each to the theological seminaries of Andover and Newton; one copy to each incorporated Atheneum, Lyceum, and Academy, in the Commonwealth; one copy to the American Academy of Arts and Sciences; one copy to the Antiquarian Society at Worcester, and one to the Pilgrim Society at Plymouth; one copy to the Massachusetts Historical Society, and to every other incorporated historical Society in the Commonwealth; one copy to the State Lunatic Hospital at Worcester; one copy to the Boston Society of Natural History; one copy to the Essex County Natural History Society; one copy each to the Massachusetts and Salem Charitable Mechanic Associations; one copy to the library of the East India Marine Society, in Salem; two copies to the library of the United States; one copy to the Executive of each State in the Union; one hundred copies to be placed at the disposal of the Governor, and the remainder to be subject to the further order of the Legislature.

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## *Errata.*

Only the following Errors of much importance have yet been noticed. Many in orthography and punctuation will undoubtedly be found; but it is hardly necessary to notice any here, unless they are such as to mislead the reader.

p. 49, line 20 from top, for 241 and 242, read 185 and 187: make the same correction in lines 25 and 28 from top.

p. 125, in the caption of the composition of crenic acid, transpose *oxygen* and *carbon*.

p. 325, line 17 from top, for *at* read *as*.

p. 358, line 5 from bottom, after *abutments* add, *and piers*.

p. 423, at top, for Plate 55, read, Plate 54.

p. 425, line 14 from top, for Plate 55, read, Plate 54.

p. 807 against No. 2591, for *Wrentham*, read *Mansfield*: and against No. 2592 for the right hand *do*, read *Wrentham*.

# POSTSCRIPT.

In sciences pursued with so much zeal and ability as Geology and Chemistry at the present day, the lapse of a year often brings out important discoveries. During the longer period in which this Report has been in press, some developments have been made important enough in my opinion to demand a Postcript. They are inserted at the beginning of the Report, both because of their importance, and because of the well known fact that this is the last part of a work that is printed.

## *New Work on Organic Chemistry.*

Professor Liebig of the University of Giessen, has recently published a work on *Organic Chemistry in its applications to Agriculture and Physiology*, which contains many new views in relation to the nutrition and development of plants. All these views, coming as they do from one of the most distinguished organic chemists living, will be examined by scientific men with great respect, and some of them adopted at once as obvious discoveries and improvements. He seems to have proved that the atmosphere contains ammonia, and justly imputes much to its agency in the growth of plants. Indeed, he makes nitrogen much more important in vegetation than has been supposed. He maintains that the favorable influence of gypsum results from its fixing the ammonia of the atmosphere in the soil by converting it into a sulphate. The important principle suggested and defended by Dr. Dana, and confirmed by all the analyses given in this Report, that phosphates exist naturally in all soils, is also maintained by Liebig, without any knowledge of course that the same view had been taken on this side of the Atlantic. His suggestions respecting the rationale of a rotation of crops, and many other points in practical agriculture, are ingenious and important.

As to the manner in which plants are nourished, Liebig adopts the opinion of Raspail, that their carbon is derived wholly from the imbibition of carbonic acid, either from the atmosphere or the soil. He denies that they absorb geine, or any of its compounds, as nourishment; and he supposes that the geine (humus, or humic acid,) acts only as a means of generating carbonic acid by the changes which it undergoes. It is not my intention to go into any argument on these points in this postscript. But it is a little curious, that Liebig, in attempting to show that there are no means in soils for dissolving more than an infinitessimal quantity of geine, should have overlooked the two most important means of its solution. He supposes that rain water is the only agent in this work. But growing plants have the power of decomposing silicates, and thus of setting free potassa and other bases eminently adapted for the solution of geine. Again, the changes which geine undergoes in the soil produce a great quantity of water, sufficient, according to Nicholson's Journal, to cause an evaporation of 5000 pounds per hour from a well manured acre: quite equal to that resulting from the most copious rains. (*See Webster's Liebig, p. 398.*)

The views of Dr. Dana on these points, I ought perhaps to remark, are those which have most widely prevailed among scientific men in modern times, viz. that plants derive their nourishment partly by absorption from the atmosphere, and partly by taking up soluble matters from the soil. He admits even, that they may absorb carbonic acid by their roots; nor does he decide upon the exact proportion in which nourishment is derived from these different sources. Indeed, it would not be surprising if it should appear, that plants have such a power of adapting themselves to different circumstances, that they might sometimes sustain themselves exclusively from the atmosphere, and sometimes from the soil: sometimes by carbonic acid alone, and sometimes by geine alone. If such be the case, it might reconcile some of the conflicting experiments and opinions on this subject.

## *Organic Matters in Soils.*

Although chemists have long been agreed that several distinct compounds exist in the organic matter of soils, they are not agreed as to their exact number. According to Dr. C. T. Jackson, Berzelius, the distinguished chemist who first proposed the term geine, in a late edition of his Chemistry has dropped that term, and substituted for it that of humic acid. He has also substituted *humin* for carbonaceous mould. He still employs the terms crenic and apocrenic acid, and extract of humus; and these substances, with humic acid and humin, and occasionally traces of glairin, embrace all yet detected in the organic matter of soils, which he denominates humus. This humus corresponds to the geine of Dr. Dana, when he uses that term agriculturally. He then embraces in it crenic and apocrenic acid, humic acid, and humin; which he regards as forms of geine; divided by him into two classes, the soluble and insoluble. It is in this sense that the term geine is used in Dr. Dana's rules of analysis given in this Report. It is true, when he uses the term chemically, he means the same by it as Berzelius does by humic acid: though as the extract of humus and humin of the same author, do not differ in composition from the humic acid, these also are embraced in geine. Dr. Dana, however, would not have given his views concerning the chemical nature of geine, had he not been requested: for he does not regard this essential in treating the subject agriculturally. In a letter to Mr. Colman, the Agricultural Surveyor, he says, "whether we consider geine as a simple substance, or composed of several others called crenic, apocrenic, puteanic, ulmic acids, glairin, apotheme, extract of humus, or mould, agriculture ever has considered it, and probably ever will consider it one and the same thing, requiring always similar treatment to render it soluble when produced; similar treatment to render it an effectual manure."

According to these views, whose truth is founded not on theory but experience, we can see how analyses of soils may be usefully conducted according to Dr. Dana's rules, even though there be a diversity of opinion among learned men as to the chemical nature of the organic matter of soils, and the mode in which plants are nourished. For whether geine consists of one or twenty substances, and whether it be directly imbibed by plants, or only furnish carbonic acid, the fact still remains equally true, that the fertility of a soil depends in a good degree upon the amount of soluble geine which it contains.

These remarks seemed to me important to prevent a misapprehension of the language and principles of Dr. Dana in this Report.

1a

## *Distribution of Sea Shells.*

In Dr. Gould's Report on the Mollusca of Massachusetts just published, a fact of no small geological interest is given respecting the marine shells found on the opposite sides of Cape Cod. I present it in his own language.

"The distribution of the marine shells is well worthy of notice as a geological fact. Cape Cod, the right arm of the Commonwealth, reaches out into the ocean some fifty or sixty miles. It is no where many miles wide, but this narrow point of land has hitherto proved a barrier to the migrations of many species of *Mollusca*. Several genera and numerous species, which are separated by the intervention of only a few miles of land, are effectually prevented from mingling by the Cape, and do not pass from one side to the other. No specimen of *Cochlodesma*, *Montacuta*, *Cumingia*, *Corbula*, *Ianthina*, *Tornatella*, *Vermetus*, *Columbella*, *Cerithium*, *Pyrula* or *Ranella*, has as yet been found to the north of Cape Cod; while *Panopea*, *Glycymeris*, *Terebratula*, *Cemoria*, *Trichotropis*, *Rostellaria*, *Cancellaria*, and probably *Cyprina* and *Cardita*, do not seem to have passed to the south of it. Of the 197 marine species, 83 do not pass to the south shore, and 50 are not found on the north shore of the Cape. The remaining 64 take a wider range, and are found on both sides."

## *Report on the Fossil Footmarks.*

In my account of the fossil footmarks in the Connecticut valley, I have quoted the opinion of two distinguished European geologists concerning them. I have now the satisfaction of giving the views of several eminent geologists of our own country on the same point. At a meeting of the Association of American Geologists in Philadelphia, in April 1840, a Committee was appointed "to visit the localities and report their conclusions at the next meeting." At that meeting, held in the same city in April 1841, the following Report was presented.

## *Report on the Ornithichnites or Footmarks of extinct Birds in the New Red Sandstone of Massachusetts and Connecticut, observed and described by Prof. Hitchcock, of Amherst.*

The undersigned, forming the Committee to whom the subject of the origin of the Bird tracks of Professor Hitchcock was assigned, beg leave to present the following brief Report. It may be well previously to state, that the object of the meeting in appointing this Committee was founded solely upon the desire to produce if possible unanimity of opinion, there being a few of the members who dissented from the views published by Professor Hitchcock. In our country the subject, as it undoubtedly ought, had attracted considerable attention. It had been very favorably received and republished in Europe; and from its great importance to Palæozoic Geology, an attempt should be made to settle the question: for were the views of our highly respected member correct, we were made acquainted with the earliest period in which biped animals existed, whose footmarks were analogous to, if not identical with those of the tread of birds: On the contrary, if wrong, we were presented with another class of facts, which show that certain appearances supposed to belong solely to animal life, were held or presented by the vegetable kingdom likewise. We shall now state in a few words, what we suppose are the general facts upon which Prof. Hitchcock's views were founded, and then the facts of those who assumed the opposite opinion. The first and most obvious impression upon the mind on looking at the indentations or marks, is their tri-partite form, resembling the tread or footmarks of those kinds of Birds, which have three toes, the fourth one being rudimental, and are referrible to no other known kind of animal. The tracks or footmarks in several localities are arranged in a determinate order, like those of a bird or fowl, moving in a straight line: the toes or marks in all such cases being alternate; that is, if the right foot be presented on the rock, the left would next follow, and thus right and left in regular succession, sometimes with many repetitions. In other instances the footmarks presented no determinate direction or order, as might naturally be supposed of a bird or any other animal having no particular place or object in view. In all cases where a succession of tracks was observed, there was an uniform correspondence as to size, and considerable regularity as to distance, between the tracks. Whatever deviations were observed, they were not greater than might be supposed to take place in animals possessed of voluntary motion. On some surfaces not unfrequently one or more different kinds of tracks were exposed, belonging, as was reasonably conjectured, to different species and genera of Ornithichnites. That the slaty material of the rock showed that the impressing body possessed force or weight, for frequently the thin layers or laminæ were bent downwards for an inch or more, and that the mud of which the slate was formed was of a highly adhesive or tenacious character. In all cases the footmarks or part impressed, was the fixed part of the rock; the part removed when the lower side was turned upwards, showed the cast or what corresponded with the toes or foot. That no trace of any organic matter could be perceived occupying the cavity or mould, the cast or part in relief being in all respects like the material of the rock of which it formed a part. Finally, that the footmarks belonged to a group of rocks which must be considered to have been produced by the same general causes which gave rise to the New Red Sandstone of Europe, and referrible only to that Sandstone. This Sandstone presents footmarks in many localities, though comparatively but a few years have elapsed since attention has been called to them. Some of the specimens have reached this country, and had they not, the information is well given by Dr. Buckland in his Bridgewater Treatise. The most remarkable of these footmarks is that of the Chirotherium from the quarries of Hessberg near Hildburghausen in Saxony, and greatly resembles a fleshy human hand. These in the drawing and in the specimen which we have seen, are alternated right and left. Other footmarks have been observed by Mr. Link in the same sandstone, he having made out four species of animals, some of which are conjectured to belong to Gigantic Batrachians. Near Dumfries the footmarks of animals, probably tortoises, were obtained from the same sandstone: but as yet no tracks like those of New England have been discovered.

The facts, &c. which led to a different conclusion are these. First, that the forms assumed by fucoidal plants were numerous and imitative; some resembling the tail of a rooster, the *Cauda Galli*. Another which was like unto a large claw or paw, and which may have been a lusus naturæ, and the two specimens on the table of the Association which present in relief a distinct tri-partite form. There as they all appertain

to rocks of great antiquity in comparison with those of New England, it appeared more reasonable to believe that there might be resemblances as perfect as the fossils with a tri-partite character, were but approximations to the forms in question. That no trace of organic matter could be discovered by the eye, in the greater number of the Fucoides. In some such as the Harlani, they have been seen to be made up of small pebbles, presenting no little difficulty not to the manner only in which the organic matter was replaced, the external form being complete, but the nature of their material which could make so definite an impression and preserve its form entire. There are other facts which showed resemblance such as that the part in relief, was the part removed when the fucoide was attached to sandstone at its upper part. It may also be stated that the appendages to the heel of some of the New England tracks, might have been caused by a bird whose legs were feathered, but not to a wader, and they favoured their vegetable origin, for the appendages might readily be conceived to be either leaves or radials or both. From a comparative examination of the facts on both sides, your Committee unanimously believe that the evidence entirely favours the views of Prof. Hitchcock, and should regret that a difference had existed, if they did not feel assured it would lead to greater stability of opinion. To liken things to what we know in the nature of mind, the error from this tendency increases with ignorance and diminishes as knowledge increases, so that He that knoweth all things, as is self-evident, can commit no error when following this instinct of his being. The discoveries of Prof. Hitchcock were published at a period when the mind of those who embraced the negative side of the subject was preoccupied with the anomalous vegetation which many of the Silurian rocks of New York abound and to which provisionally the name of fucoid had been given. From their imitative character, and from finding a few specimens presenting a tri-parlate or tri-furcate form, &c. it appeared not only possible, but probable, that the impressions from Massachusetts and Connecticut were with greater propriety referrible to fucoidal bodies, than to those which Prof. Hitchcock had assigned them. We may here remark how essential it is that truth, or the facts which make manifest any truth, should first be presented to us, so readily is the mind impressed when not pre-occupied, and when a strong impression is made be it ever so false, it is no easy matter to free ourselves from it. From this circumstance we can readily forsee the advantage which future generations will possess over those of the present and especially those of former times. As the progress of knowledge is certain, each day will lessen error and enlarge the domain of truth, and should man be true to his permanent interests, error will finally cease to have existence.

HENRY D. ROGERS,
LARDNER VANUXEM,
RICHARD C. TAYLOR,
EBENEZER EMMONS,
T. A. CONRAD.

## *Glacio-aqueous Action between the Tertiary and Historic Periods, denominated in my Report, Diluvial Action.*

Since the Section in this Report on Diluvium was written, I have been favoured, through the kindness of Professor Silliman of Yale College, with the perusal of a recent work by Professor Agassiz on Glaciers and Glacial action, entitled *Etudes sur les Glaciers*. I am indebted, also, to Dr. J. Pye Smith of London, for an abstract of three papers on the same subject, read last autumn before the London Geological Society, by Agassiz, Buckland, and Lyell. By the labours of these distinguished men, the whole subject of diluvium has been made to assume an aspect so new and interesting, that I am unwilling my Report should go out of my hands unaccompanied by a brief view of the facts and inferences concerning it. Perhaps I cannot better accomplish this object, than by giving, in the first place, an outline of the glacial theory, and its application to this country, in an extract from an Address recently published, which I gave before the Association of American Geologists at Philadelphia in April 1841.

"Beyond such independent inferences as these, (which had just been stated,) I confess, I have been of late years unwilling to go; and have regarded the numerous theories of diluvial action that have appeared, only as ingenious hypotheses. But it is well known that the Glacier Theory, originally suggested by M. Venetz, and subsequently by M. Charpentier, and more fully developed of late by Agassiz, is now exciting a great interest in Europe. To say nothing of geologists in this country, who have expressed themselves favorably towards it, it is surely enough to recommend it to a careful examination, to learn that such men as Agassiz, Buckland, Lyell, and Murchison, after long examination, have more or less fully adopted it; though on the other hand, it ought to be mentioned, that such geologists as Beaumont, Whewell, Sedgwick, Mantell, and others, still hesitate to receive it."

"In a country like ours, where no glaciers exist except in very high latitudes, and with the very indefinite accounts, which have hitherto been given of those in the Alps, it is not strange that this attempt to explain the vast phenomena of diluvial action by such an agency, should appear at first view, fanciful, and even puerile. But the recent work of Agassiz, entitled "*Etudes sur les Glaciers*," gives a new aspect to the subject. It is the result of observations made during five summers in the Alps, especially upon the Glaciers, about which so much has been said, but concerning which so little of geological importance has been known. Henceforth, however, glacial action must form an important chapter in geology. While reading this work and the abstracts of some papers by Agassiz, Buckland, and Lyell, on the evidence of ancient glaciers in Scotland and England, I seemed to be acquiring a new *geological sense;* and I look upon our smoothed and striated rocks, our accumulations of gravel, and the "*tout ensemble*," of diluvial phenomena, with new eyes. The fact is, that the history of glaciers is the history of diluvial agency in miniature. The object of Agassiz is, first, to describe the miniature, and then to enlarge the picture till it reaches around the globe."

"The glaciers are vast masses of ice, formed of melting and freezing snow, which are sent out from the summit of the Alps, by the force of expansion into the valleys below, sometimes to the distance of 12 or 15 miles. Those elevated and wide *plateaux*, called in Switzerland *Mers de Glace*, exhibiting only one sheet of ice, through which the crests and summits of the mountains sometimes rise like volcanos, are the grand source, or *birth-place*, of the glaciers. In their descent they plough their way through the soil, pile up pebbles and sand along their sides and at their extremities, and even upon their backs, which, upon the retreat or melting of the glaciers, constitute *moraines*, and correspond exactly in composition and shape to those

accumulations of gravel and bowlders that have been ascribed to diluvial action: The stones and sand frozen into the lower surface, also, like so many fixed diamonds, smooth and furrow the surface of the rocks in precisely the same manner as they appear over all northern countries. Vast blocks of stone are also conveyed without attrition, by the advance of the glaciers, and lodged in peculiar situations."

"From year to year the evidence has been increasing of the prevalence of intense cold in northern regions in the period immediately preceding the historic. The elephants and rhinoceros found in the frozen mud of Siberia, the arctic character of the few organic remains found in the post-tertiary strata of Scotland and Canada, as described by Lyell and Bowman, and of the borders of Lake Champlain, as described by Emmons and Conrad, and the vast extension of the ancient moraines in the Alps, are the evidence from which Agassiz infers that in that period all northern countries were covered with a vast sheet of ice, filling the valleys and extending southerly as far as diluvial phenomena have been observed. Glaciers would thus be found on mountains of moderate alttitude; and, indeed, he supposes that all the northern part of the globe might have constituted one vast *Mer de Glace*, which sent out its enormous glaciers in a southerly direction; thus giving the same direction to the drift and striæ on the rocks. As these vast masses of ice, when the temperature was raised, melted away, immense currents of water were the result, which would lift up and bear along huge icebergs, whereby extensive erosions would be produced and blocks of stone be transported to great distances. Subsequently, lakes would be formed, where moraines had produced barriers, and clay and sand would there be quietly deposited by the waters which would be ultimately drained by the wearing down of the barriers of detritus."

"It is doing injustice to this theory to attempt so brief a description of it. A detailed account of existing glaciers which cannot here be given, forms the best preparation for a just appreciation of the theory. Admitting its truth in the main, let us see how it applies to the phenomena of drift in this country."

"In the first place, it explains satisfactorily the origin of those singular accumulations of gravel and bowlders, which we meet with almost everywhere in the northern parts of our country. I cannot doubt but that these are ancient moraines, just such as exist in Scotland and England. Were this the proper place, I could point out a multitude of localities of these, most of which have been a good deal modified by subsequent aqueous agency: but some of them retain the very contour which they had, as the ice melted away. The lateral moraines are perhaps most common, especially if with Dr. Buckland we regard our terraced valleys as modifications of these; but I am confident that in our mountain valleys, the terminal and medial moraines are not infrequent. I have long been convinced that the agency of ice is essential to explain these accumulations; but I was not aware that their antitypes existed in the moraines of the Alps."

"In the second place, this theory explains in a most satisfactory manner, the smoothing, polishing and furrowing of the rocks at different altitudes. All these effects are perfectly produced beneath the glaciers in the Alps; nor can I conceive of any other agent, by which the work could be executed. It certainly was not done by currents of water alone."

"In the third place, it explains the transportation of bowlders, and their lodgment upon the crests and narrow summits of mountains; and that often without having their angles rounded."

"In the fourth place, it accounts for the existence of deposits of clay and sand above the drift. For it furnishes the requisite quantity of water to fill the valleys, and the means of damming up their outlets for a season."

"In the fifth place, it shows us why these deposits of clay and sand are almost completely destitute of organic remains, either of animals or plants, although centuries must have been consumed in their formation."

"In the sixth place, it accounts for some rare and peculiar phenomena connected with diluvial action, which seem to be inexplicable on any other known principle. I shall name only two. The first is, that the northern slopes of some of the mountains of New England, although quite steep, and their summits rounded, exhibit scratches and furrows, which commence several hundred feet below their tops, and pass over them without losing their parallelism; and yet the situation of the drift shows that these markings were made by an ascending, not a descending body. Such might be the effect, if the whole surface of the country were covered by a thick sheet of ice, expanding in a southerly direction. Of the other case, I have met with two examples in New England, and know not that they have been noticed elsewhere. In these cases the perpendicular layers of argillaceous and hornblende slate, covered in one case by 15 or 20 feet of drift, have been fractured to the depth of 10 or 15 feet, so as to be more or less separated, and so as to produce horizontal fissures, which are filled by mud; while the laminæ of the rock are inclined at various angles. In short, it seems as if an almost incredible force had been exerted upon the surface, in an oblique direction. Such a force might be exerted by an immense mass of ice, in the process of expansion; but I know of no other source from which it could have been derived." (*See Fig.* 83, *p.* 396, *and Fig.* 114, *p.* 560, *of this Report.*)

"On the other hand, there are features in the phenomena of diluvial action in this country, which are explained by this theory, in a much less satisfactory manner. One is, the southerly direction which our drift has taken, and the great distance to which it has been carried. It cannot be conceived that any single glaciers should have expanded several hundred miles in a southerly direction, especially over a surface which could have had scarcely no southern slope. Even if we admit a "Mer de Glace" in the northern regions so lofty, as in the beginning of the work to send glaciers a vast distance, yet the force seems to have continued to operate in the same austral direction, even to the bottom of our valleys. It is, however, probably true, that the great mass of our drift will be found within 15 or 20 miles of its origin, and that which occurs at greater distances may, perhaps, have been transported by powerful currents of water. It is almost certain that the sheets of ice which covered the surface according to this theory, must have been at least 3000 or 4000 feet thick; because our mountains to that height have been swept over. Now, if as Agassiz and others suppose, the fall of temperature at the beginning of the glacial period was very sudden, why may not the return of the heat have been equally sudden? If so, the most powerful debacles must have been the result;* and as the ice would disappear most rapidly along its southern border, perhaps in this way a

* A curious example illustrative of this point has just been communicated to me by Rev. Justin Perkins, American Missionary at Oroomiah, in Persia, not far from Mount Ararat, in a letter of Nov. 6th, 1840. In giving an account of two very powerful earthquakes experienced on and around the mountain in the summer of last year, he says; "the vast accumulation of snow which had been increasing on and about the top of the mountains for centuries, was broken into pieces, and parts of it shaken down on the

current in that direction may have been produced. And yet, I confess that I regard this theory more defective in not furnishing an adequate cause for the southerly course of our drift, than in any other point."

"I find another difficulty in explaining satisfactorily by this theory, how drift could have been often carried from lower to much higher levels; as it has been sometimes, without doubt. Thus, the Silurian rocks of New York and the quartz rock in the western parts of Massachusetts, have been carried over Hoosac and Taconic mountains and the Highlands of New York. It is easy to conceive how an immense sheet of ice, by its expansive power, should force portions of its mass to ascend declivities, of a few hundred feet; but not so easy to imagine them thus forced upward 1000 or 2000 feet.

"Another difficulty results from the fact, that some of the most remarkable of our moraines are found, not in valleys, but on the sea-coast, some of them 50 and others 100 miles distant from any mountain, much higher than themselves. I refer to those remarkable conical and oblong tumuli of drift, sometimes more than 200 feet high, which occur in Plymouth and Barnstable Counties in Massachusetts. I see nothing in this theory that will explain such astonishing accumulations in such circumstances; and yet their existence may not militate against its truth. For even the present mighty glaciers of the Alps, may give us but a faint idea of the advance and retreat of a sheet of ice thousands of feet thick."

"I do not mention these difficulties, (to which I might add more,) as any strong evidence against this theory. For so remarkably does it solve most of the phenomena of diluvial action, that I am constrained to believe its fundamental principle to be founded in truth. Modifications it may require: for it would be strange indeed, if it had already attained perfection, even in the skilful hands that have thus far formed and fashioned it. But I can hardly doubt that *glacio-aqueous* action has been the controlling power in producing the phenomena of drift. Having hovered so long over the shoreless and troubled ocean of uncertainty and doubt, I may be too ready to alight on what looks like *terra firma*. But should it prove a Delos, I have only to plume my wings again, when it sinks beneath the waves."

It may give a more definite idea of the nature of glaciers and of some of the phenomena connected with them, to insert a few cuts, copied on a reduced scale from the splendid drawings accompanying the *Etudes sur les Glaciers* by Agassiz. Fig. 276, exhibits the glacier of Aletsch, one of the largest in the Alps, where it enters the lake of Aletsch which it has formerly caused to overflow with wide spread havoc. Large blocks frequently break off from this glacier and float about as icebergs in the lake.

Fig. 276.

*Glacier and Lake of Aletsch.*

Fig. 278, exhibits the lower extremity of the Glacier of Viesch, with a distinct terminal moraine, which at the sides is connected with lateral moraines. From beneath the Glacier issues a stream of water, as is always the case in summer. This has worn a channel into the rocks below the glacier, and the surface of those same rocks is smoothed and striated by the former action of glaciers; so that here is exhibited glacial and aqueous action side by side. The conical bodies on the top of the glacier are needles of ice called *Aiguilles*, formed by the inequality of the surface beneath, and the melting of the ice above They are shown also on Fig. 277.

sides of the mountains in such immense quantities, that (it being midsummer and the snow descending down as far as a warm climate and suddenly melting,) torrents of water came rolling down the remainder of the mountain, and flooded the plain for some distance around its base."

Fig. 277.

*Glacier of Viesch in the Alps.*

In Fig. 277, we have a view of the upper part of the glacier, of Viesch, as it proceeds from the distant *mer de Glace*, and winds through the long valley. At its sides may be seen lateral, and on its top, medial moraines; considerably disturbed, however by the serpentine course of the valley.

Figs. 279 and 280, represent smoothed and striated masses of schistose serpentine, produced by the expansion of the glacier. Fig. 279, shows two sets of scratches, crossing each other at a considerable angle. Yet the striæ belonging to each set preserve their parallelism most perfectly.

Any one conversant with the smoothed and striated rocks of this country will be struck with their exact resemblance to the above. It is not unusual also, to meet with surfaces with two sets of striæ diverging slightly, as in Fig. 280. This is often the case, according to Professor Locke, upon the polished limestones of Ohio. Fig 281 is a case of this kind, copied from the crest of Mount Monadnoc in New Hampshire. The two sets of scratches diverge only 10,° and it is not common to see a much greater divergence.

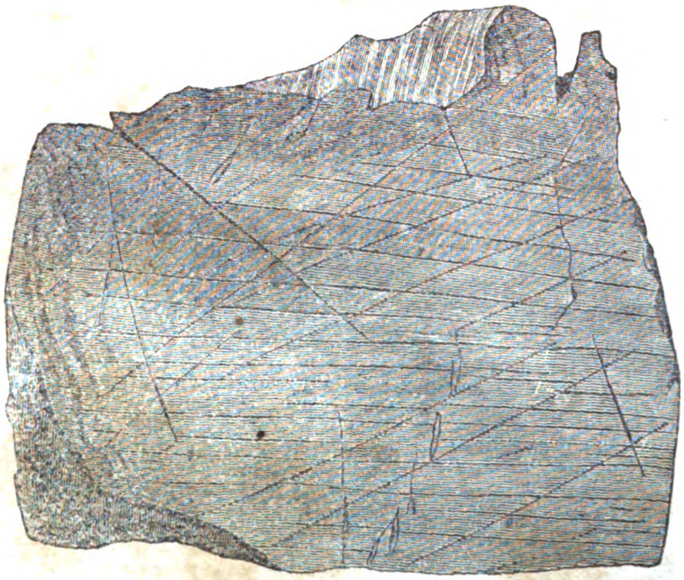
Another effect of glaciers has its counterpart among our diluvial phenomena. The ice so rounds off the angles of rocks as to give them an embossed form; and hence such rocks in the Alps were called by Saussure, *Roches moutonnees*. An example of this effect,—though less striking than others exhibited on the plates of Agassiz, (*Etudes sur les Glaciers*,) is shown on Fig. 277, at its lower part, and on Fig. 278 more distinctly. This same appearance is frequent upon the rocks of Massachusetts: but one of the most distinct examples that I have ever seen, occurs on Mount Monadnoc in New Hampshire. A large part of the crest of that mountain, and its northern and northwestern slopes, are covered with these protuberant and rounded rocks, whose surfaces often show distinct striæ. An attempt is made in Fig. 282, to represent the aspect of one spot about 5 rods square on the crest of the spur of Monadnoc that runs southwest from the body of the mountain. In taking the sketch the eye was directed southeasterly, which was the course there taken by the glacial agency. Hence the protuberances appear more like spherical domes than they are in reality; because they are generally much longer in a southeast and northwest direction than in any other. This spot is not less than 600 or 700 feet below the summit of the mountain; but the same appearance is common even almost to the apex.

On page 389 of this Report, I have given a brief account of diluvial action on Monadnoc, derived from my assistant, Mr. Abraham Jenkins, Jr. The interest which his description excited, has led me within a few days past to visit that mountain, and I found it prolific in the marks of former glacial action. It consists of a ridge of mica slate, running nearly S. W. and N. E. near whose center rises a vast pile of naked rock, several hundred feet above its northeastern and southwestern wings, which are also in a great measure naked. On almost every part of it, from its base to its summit, it bears the marks of a powerful abrading agency: and the region around the mountain, the hills as well as the valleys in its vicinity, abound with striated rocks, angular blocks of stone, and occasional moraines. The direction of the markings around Monadnoc and upon its southeastern part, is nearly N. W. and S. E.; but near the summit of the mountain they approach more nearly to the meridian, as near sometimes as 10° by the compass.

Fig. 278.

*Glacier of Viesch, with terminal and lateral Moraines.*

Fig. 279.

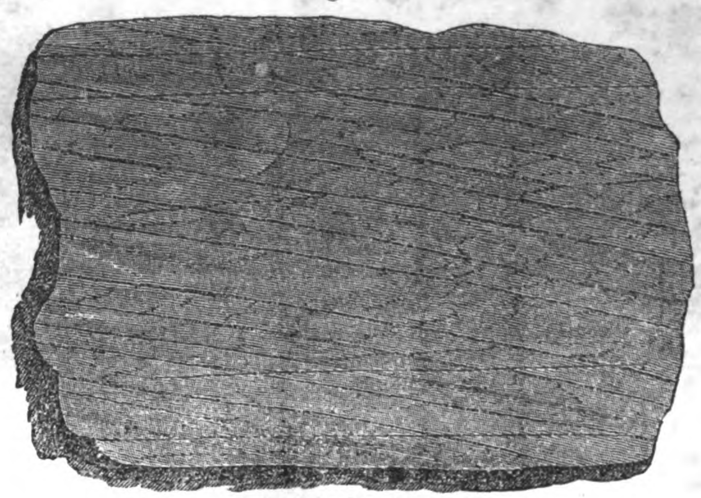


*Rock striated by Glaciers.*

Fig. 280.

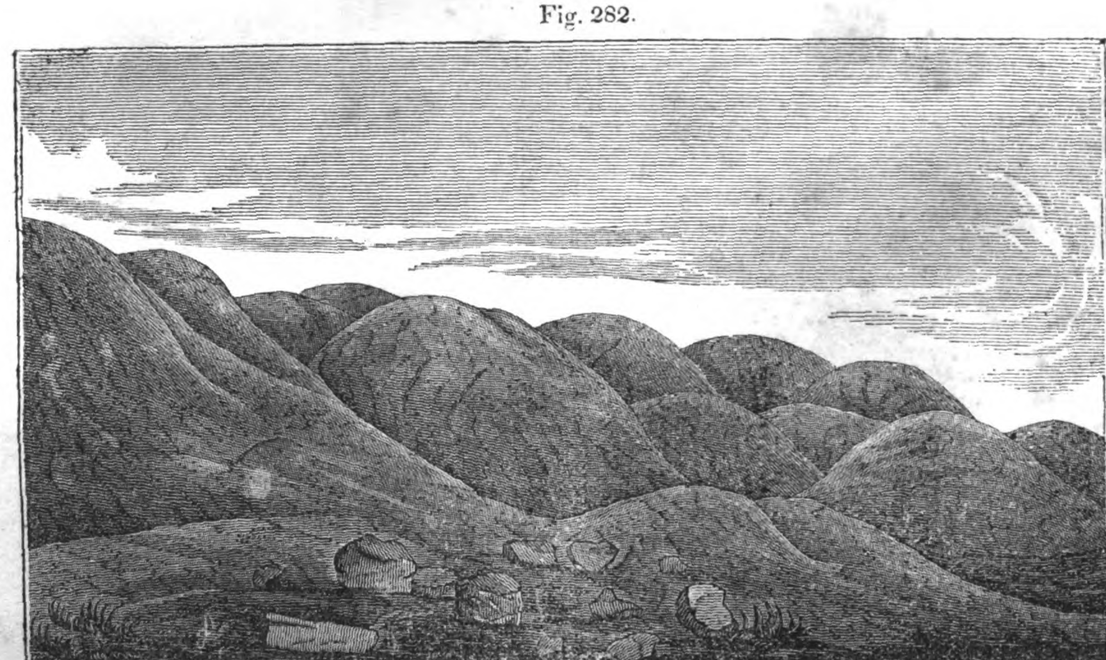
*Rock striated by Glaciers.*

Fig. 281.



*Striated Rock: Monadnoc.*

Fig. 282.



*Embossed Rocks (Roches moutonnees): Monadnoc.*

There are several peculiarities in what have been called the diluvial phenomena of this mountain, with which I should have been exceedingly perplexed, had I not read the recent *Etudes sur les Glaciers* by Agassiz. The striæ on the rocks are not as distinct as in many other places, and the difficulty of observing them is increased by the fact that over a considerable portion of the southwest part of the mountain, the strike of the laminæ of slate coincides very nearly with that of the scratches. Nevertheless, they may generally be distinguished by the practised eye, and on a large part of the mountain they cross the edges of the slate at a considerable angle. They are frequently visible on the sides of the ledges; and on the north side of the principal peak, they are sometimes seen on slopes from 20° to 70°. And what is still more unusual, they are seen on the southeast side of the principal summit, where the slope is steep, and several hundred feet below the top. But the *roches moutonnees* are the most striking peculiarity of the phenomena under consideration. Almost every part of the mountain, except its steep southeasterly side, is covered by these irregular rounded protuberances, which have almost every possible form; but their longer axis corresponds almost invariably with the direction of the grooves and striæ. Looking in a southeasterly direction they sometimes have the appearance represented on Fig. 282; but looking at them from other positions, they considerably resemble the swells of the ocean in a calm day after a storm. Frequently too the effects of ice in recent times, is seen in breaking up the surface of the rock more or less into fragments. If we face the northwest, even when among these rounded rocks, we see but little of the *moutonnees* appearance, because their southeastern extremities are not rounded: and there, indeed, (as at a spot few rods east of the summit of the mountain,) we see where large masses of the rock have been forced out of their places and carried away. Few loose transported blocks now remain upon the mountain.

The facts stated above relative to the occurrence of striæ on the north and south slopes of Monadnoc, might lead to the conclusion that they were the result of glaciers sliding down each way from the summit. But the fact that the *roches moutonnees* are rounded only upon their northwestern side, shows that the force which has produced these effects had a southeasterly direction. Indeed, I see no way to avoid the conclusion that the ice, which probably was the agent, must have been forced upward over the top of this mountain. I descended on the north side only a few hundred feet, but could see downward nearly to the bottom, and the same appearances presented themselves as near the top. Were the whole of the surrounding region covered with a vast sheet of ice, I can easily conceive how its expansion might have accomplished such a work. Indeed, so nearly irresistible must such a force have been, that either the mountain must have been crowded out of its place, or the ice have been swelled upward and forced over it. Such an operation must have broken the ice considerably, and this may explain the irregularity of its action towards the summit of the mountain, which is greater than I have witnessed in any other place.

If these views are correct, we cannot probably infer that the sheet of ice which covered New England was quite as thick as the height of Monadnoc; because it might have been swelled up considerably at this place. But the marks of its action at the top of the mountain are too striking to suppose the swell to have been very much above the general surface: otherwise the ice would have been tilted over and left no trace of its action. The downward force at the top must have been nearly as great as in any other part, and therefore a great thickness of ice must have been forced over it.

The important bearing of these details upon the theory of glacial action, is the reason I have given them; although Monadnoc lies a few miles out of the limits of the state. But whatever glacial action has taken place there, we may be quite sure has extended into Massachusetts. And indeed, I have pointed out similar phenomena there in the following Report.

## *Moraines.*

After reading the work of Agassiz on Glaciers, and an abstract of the papers of Agassiz, Buckland, and Lyell, on the evidence of former glacial action in Scotland and the north of England, I cannot doubt but ancient moraines are scattered all over New England. The most remarkable of these I have described and figured in this Report. (See Wood Cuts, figs. 15, 19, 73 and 74, and Plate 3.) In the work of Agassiz I do not indeed find a description of any of those singular insulated or grouped tumuli of sand and gravel, which are so common in this country, and some of which are shown in the drawings above referred to. But it cannot be doubted that Dr. Buckland describes the same phenomenon in Scotland, when he says that "thirty or forty round-topped moraines, from 30 to 60 feet high, are crowded together like sepulchral tumuli," and he adds, that "they exactly resemble some of the moraines in the valley of the Rhone, between Martigny and Loek." Similar accumulations are common, according to him, in Scotland. I regret that he has not described under what peculiar circumstances such singular moraines are formed: for I own myself perplexed to conceive how: especially as the largest examples occur with us far away from any elevated land. I refer to those in Plymouth and Barnstable Counties. And yet, I shall be likely to regard the fact, that without any definite knowledge of the action of glaciers, I have in this Report called in the aid of ice to explain these mounds of gravel and sand, as some presumption in favor of their glacial origin. But how came such enormous moraines to be found in the low and comparatively level country where they exist? Is it possible that the whole of Cape Cod is nothing but a vast terminal moraine, produced by a glacier advancing through Massachusetts Bay, and scooping out the materials that now form the Cape? In this case the moraines at Plymouth and Truro would form a part of the lateral moraines, and probably most of Nantucket and Martha's Vineyard might be regarded as moraines of the same glacier, when it extended farther south. But the fact that laminated clay occurs so often upon the Cape, is a strong objection to such an hypothesis. The occurrence of so many ponds in connection with the moraines of Plymouth, Sandwich, and especially Falmouth, is readily explained by the glacier theory; since such effects are often thus produced in the Alps.

My attention was called to the new views of this subject, in season to mark on the proof sheet of Plate 53, which exhibits some of the phenomena of drift in Massachusetts, the most remarkable examples of moraines occurring in the State. These have, indeed, been described under another name in the following Report. It will be seen that many of the most remarkable of these occur far away from mountains and valleys, in the eastern part of the State, as at Truro, Sandwich, Falmouth, Plymouth, Wrentham, and Groton Interesting examples exist, also, in Andover; but here the country is more uneven. As we proceed to the more hil-

ly parts of the State, it must be confessed that the moraines are the largest and most striking at the foot of the mountains, and especially near gorges in the valleys. The more elevated parts of country are, indeed, often thickly strewed over with loose blocks; but generally they are not much rounded, and appear as if they resulted from medial moraines, very much scattered. Essex county abounds with such examples, particularly on Cape Ann. (See Figs. 27, 28.) They abound also over the greater part of Worcester county, particularly as we ascend the western slope of Worcester valley.

So far as I have been able, I have recently re-examined the accumulations of gravel and bowlders in the State, to see whether they could be explained by glacial action. I find it often very difficult to recognise the different sorts of moraines; but think the lateral moraines most common and distinct. Thus, along the whole extent of the great valleys of Connecticut and of Berkshire county, we find lateral moraines evidently considerably modified and enlarged by those at the *debouche* of the smaller lateral valleys. The moraine on the western side of these great valleys is far less striking than on their eastern side. I cannot explain this fact, except by saying that the force which formed these moraines, acted in a southeasterly direction, so as to cross the principal valleys (as a glance at Plate 53 will show,) at a considerable angle. But it is not so easy to see how this is consistent with the idea that the moraines were formed by glaciers passing longitudinally through these valleys.

In the south part of Montague and northwest part of Leverett, is an interesting group of moraines. A narrow valley intervenes here between Mount Toby on the west, and the primary hills on the east; and it is at the entrance of this valley on the north, that we find both terminal and lateral moraines. The most southerly of these are pushed a considerable distance into the valley, the detritus (mostly gravel,) showing a northern origin. But the largest accumulations are a little north of the opening of the valley: as if the detritus had been pushed thus far, but could not be forced into the narrow valley. As we follow the valley southerly, we find remnants of lateral moraines wherever a recess exists protected by the salient sides of the valley. Towards its southern part, a wide field of many hundred acres, entirely level, is strewed over with rounded stones, 4 or 5 inches in diameter, either by glacial or aqueous action: an occurrence which I have scarcely met any where else. Large quantities of sand and some gravel are pushed southerly a little beyond the opening of this valley, into Sunderland and Amherst; but whether by glacial or aqueous agency I am uncertain: probably by both.

Between the eastern extremity of Holyoke and the primary ranges in Belchertown, is a narrow gorge where we witness moraines similar to those in Montague. In my report I have described three ponds situated in this gorge, in such a manner as to empty at both extremities. I am now satisfied that the different ponds resulted from several terminal moraines, produced by a retreating mass of ice. North of the gorge for several miles, we find extensive moraines, which might perhaps be regarded as vast lateral moraines, though I apprehend here was a blending of terminal and lateral moraines. In this group occur the singular tumuli and tortuous ridges of gravel, exhibited imperfectly in Fig. 73 of this Report.

On the east side of the gorge above described, we find moraines at a much higher level than those just described; and from this case, as well as others, I infer that the glacial action must have taken place at different levels. In other words, one mass of ice must have advanced southeasterly and have produced the more elevated moraines, while yet the lower part of the valleys were filled with ice, which adhered to the surface. If such were the case we see why it is that the moraines are so blended and irregular. I acknowledge, however, that the upper moraines may have been pushed to their present height by the expansive force of the ice, even from the bottom of the valleys; and the lowest ones have been produced by its retreat. The remarkable denudation of Mount Holyoke, however, described on page 389, of the following Report, I cannot explain without supposing the surrounding valleys filled at first with ice nearly to the top of that mountain, and then that another mass of ice, loaded with detritus, was slid over this surface, and commenced the work of furrowing out the remarkable valleys existing on its top. This would account for the parallelism preserved by those valleys; (called in Switzerland *Lapiaz or Lapiz.*) but the work must have been afterwards carried on partly by water, loaded probably by ice and detritus, as the ice gradually melted away. For such troughs (*Lapiaz*) in the Alps are found due in a measure to water. And yet, the denuding effects of ice must have continued even to the bottom of these valleys: for their sides show those peculiar striæ that can be the result only of the advance of masses of ice. In short, it seems to me that the striated and polished rocks, the *lapiaz*, or valleys of erosion, and the moraines of New England, show, that almost to the commencement of the historic period, there was a conjoint action of ice and water: And if the ice must have been 2000 or 3000 feet thick, it could not have melted away without the production of immense currents. Indeed, the term *diluvial* would probably be scarcely a misnomer, as applied to the last part of what seems to me now more appropriately termed the *glacial* period.

Through the middle of Amherst, from Mount Toby to Mount Holyoke, not less than eight miles, there extends a high and broad ridge of gravel and bowlders, interrupted, however, by two small streams and other depressions. On the west side of this ridge, lies the valley of Connecticut river: and on the east, a narrow valley separates it from the high hills of Pelham. Rocks in place sometimes rise through the gravel of this ridge and I am inclined to believe that the drift ought to be regarded as the union of two lateral moraines, (which, if I understand it, forms a medial moraine,) produced by glaciers in the two valleys above named. But this ridge is a good deal broken, and several minor ridges appear as if they might have been parts of terminal moraines. Of this description is the hill on which stands the College. But here, as in other parts of the state, it is impossible, I apprehend, so far as I can judge from the accurate description of Agassiz, to trace out such distinct moraines as exist in the Alps. Indeed, this writer says, that when he advanced beyond the valleys of the Alps, he could not find terminal moraines: and that "in open valleys and broad plains the phenomena of the moraines is completely changed from what it is in the narrow valleys of the Alps."

One of the changes to which the moraines have in some places been subject in this country, is that produced by the subsequent action of currents of water. In this way the detritus has been removed from the moraine where it was originally left, and redeposited by water; and hence the examples which I have given in this Report of a stratified and laminar arrangement of the sand and gravel of our drift. In this way, also, tumuli may have been formed out of lateral moraines by streams of water descending from the neighbouring hills: as perhaps may have been done in the formation of the tumuli in North Adams, sketched on Plate 3, and those on Figs. 15 and 19: though I doubt whether the last example was thus produced. I suspect it to be rather a part of a terminal moraine.

Moraines are abundant in the west part of Northampton, commencing at Round Hill, and in the east part of Granby, at the foot of Belchertown hills. But I have not found time to examine them with sufficient care to go into details.

Upon the whole, I think that the most striking examples of moraines in the mountainous parts of Massachusetts, occur where smaller lateral valleys intersect larger ones. I have mentioned one case of this kind in Amherst. Another good example is in Athol, a little north of the middle of the town, where the two branches of Miller's river unite. If I mistake not, several terminal moraines may be seen there, cut through by the river. The principal part of the drift appears to have been brought down the valley running north and south. Other examples occur on the east side of the principal valley in Berkshire, as we ascend Hoosac mountain through the lateral valleys that *debouch* in Lee and Dalton. Similar phenomena may be seen all along the Western Slope of Hoosac mountain, where the moraines and the detritus of moraines and the erratic blocks are exceedingly abundant.

Dr. Buckland regards the "parallel terraces" of Scotland, as "the effects of lakes produced by glaciers." In regard to similar phenomena in Massachusetts, described in this Report under the name of *terraced valleys*, I do not feel prepared to give a decided opinion. I will only refer to the terraces seen in the basin of Deerfield meadows. The most elevated of these are certainly composed almost wholly of horizontal layers of clay, deposited above the drift, which clay was subsequently carried away from the central parts of the valley, so as to leave a margin of clay. In this case no glacial agency could have been concerned, except perhaps to form the lake in which the clay was deposited. I think the terraced valleys in Westfield will be found similar to those in Deerfield. But others may have been produced by ice, whose moraines were subsequently modified by water.

To conclude: the theory of glacial action has imparted a fresh and a lively interest to the diluvial phenomena of this country. It certainly explains most of those phenomena in a satisfactory manner. It seems to me, however, that the term *Glacio-aqueous action* more accurately express this agency than the term *glacial action*: for the effects referrible to water are scarcely less than those produced by ice. I could wish that the theory gave a more satisfactory explanation of the southerly direction taken by the drift. Perhaps this is a point which can be only hypothetically solved. It may have been connected with the cause which introduced the glacial epoch. Whether this came in suddenly, as Agassiz supposes, or slowly, as Lyell maintains, we know of no cause now in operation that could have produced the change from a tropical to more than an arctic climate, and then back again to a temperate climate. Is it possible that the earth, after having assumed its present spheroidal form, and nourished successive races of animals and plants in some genial sphere, was suddenly deprived of external light and heat, and of its motion on its axis, and exposed to the severe cold of the celestial spaces (—58° Fahr.) Its waters would retreat towards the poles and become ice. Let it next be placed in its present orbit and commence its present motions: and would not the ice, as it melted, both from its expansive and centrifugal force, take a southerly direction? But I forbear: for enough of dreamy hypotheses on this subject have already had an ephemeral existence, and passed onward into the caves of oblivion.

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## *Additional Errata.*

p. 356, line 6 from top, for *most* read *not*.
p. 475, line 4 from top, for *rarely* read *nearly*.

## PART I.

# ECONOMICAL GEOLOGY

OF

## MASSACHUSETTS.

THE commissions with which I have been honored by the Government, for a Survey of the Geology and Natural History of Massachusetts, have directed my attention to the following leading objects.

First, to collect, examine, and analyze, all the varieties of our soils; and to suggest means for their amendment.

Secondly, to search after, and to describe, all those varieties of marl, coal, ores, rocks, and other minerals, that are of pecuniary value.

Thirdly, to describe the most interesting features of our natural Scenery.

Fourthly, to describe the rocks of the state scientifically.

Fifthly, to collect specimens of all our soils, rocks, and minerals, for a State Collection.

Sixthly, to construct a Geological Map of the State.

Seventhly, to prepare Catalogues of the Plants and Animals found naturally within the limits of the State.

In the Reports which I have heretofore made, I have embraced all these objects to a greater or less extent. But as the facts which I have given are scattered in different reports, I propose in this report to bring them together in systematic order; and to incorporate with them other facts, which have been brought to light since my last communication to the Government; that they may have a connected view of the geological resources and the related interesting phenomena in the State. I have thought this a better course than to present a mere supplement to my former reports; which must either presuppose so much acquaintance with former reports as to make it obscure, or refer so often to facts detailed elsewhere, as to make it equally voluminous; while it would be less satisfactory than an entirely new report. But since a new Commission has recently been constituted for Botany and Zoology, com-

posed in many cases of the very gentlemen to whom I formerly resorted for help, I may now pass by these subjects, and confine my attention to our Mineralogy and Geology.

## THE GEOLOGY AND CHEMISTRY OF SOILS.

The Economical Geology of the State will first receive attention. This will embrace the two first objects of my commission as stated above. The subject of Soils—their origin and nature—analysis and amelioration—sometimes called Agricultural Geology—will first come under consideration.

### *Origin and Nature of Soils.*

All geologists and chemists agree in regarding soils as the result of the abrasion, disintegration, and decomposition of rocks, with the addition of certain saline, vegetable, and animal substances. Ever since the deposition of rocks, various agents have been operating upon them to wear them down, to cause them to crumble or disintegrate, and often to decompose them into their proximate or ultimate principles, while they have been constantly receiving vegetable and animal substances with soluble salts. The earthy portions, however, always constitute by far the largest part; and hence, if we know the composition of the rocks whence they were derived, we shall know the earthy and metallic constituents of the soil. Now we find that nearly all the rocks which exist in large quantity, are composed chiefly of silica, alumina, lime, and oxide of iron: and these are the ingredients that are found almost invariably in soils. Magnesia is also usually present in small quantity; as is also manganese in some soils. Silica is in the largest quantity, both in the rocks and the soils; alumina next; while the other ingredients are in much smaller proportion. I ought, also, to add potassa and soda; which are very widely diffused, though not usually in large quantity. To give a numerical statement, derived from numerous analyses, such rocks as most of those in New England contain 66 per cent, of silica, 16 per cent, of alumina, 6 or 7 per cent, of potassa, 5 per cent, of oxide of iron, and of lime and magnesia a less quantity: and the composition of our soils will probably be found to correspond very nearly with these numbers, with the exception, perhaps, of the potassa which may have in a good measure disappeared by the operation of vegetation.

A large part of most soils being merely rocks reduced to minute fragments without being decomposed, will as remarked above, be of the same chemical composition as those rocks. Now in almost all cases rocks are composed mainly of silicates; viz. the silicates of alumina, lime, magnesia, iron, potassa,

soda, &c. In a region where limestone predominates, we might expect, and do sometimes find, that a considerable proportion of the soil is made up of carbonate of lime. Yet this substance is more liable to decomposition than the silicates, and often a large part of it is converted by the action of living and dead vegetable and animal matter into other combinations. Thus decomposed manures form what is called geine or rather geic acid; and this unites with lime forming a geate of lime. Geates of alumina and magnesia are formed in the same manner. Living vegetables also contain generally sulphate and phosphate of lime; and by the decomposition of these vegetables, these salts will be widely disseminated through the soils. But this subject will be better understood when I have given further details.

## *Classification of Soils.*

The above ingredients are combined in different proportions in the different rocks, so as to constitute several sorts. Hence we should expect, and in fact we find, a corresponding difference in the soils resulting from their decomposition. Indeed, with some exceptions, the geologist is able to ascertain the nature of the rock from the character of the soil that covers it. And I apprehend that it will not be difficult to point out the characteristics of the soils derived from the different rock formations of Massachusetts, so that they can be distinguished by those not familiar with practical geology. This Geological Classification is the only one which I shall attempt to give of our soils; and this seems to me all that is necessary, or useful, in addition to the common division into sandy, clayey, loamy, calcareous, &c. The following list embraces, it appears to me, all the important varieties of soil in Massachusetts.

1. Alluvium, from rivers.
   Do. peaty.
2. Diluvium, sandy and gravelly.
   Do. argillaceous.
3. Tertiary soil, argillaceous.
   Do. sandy.
4. Sandstone soil, red.
   Do. gray.
5. Graywacke soil, conglomerate.
   Do. slaty, gray.
   Do. slaty, red.
6. Clay slate soil.
7. Limestone soil, magnesian.
   Do. common.

8. Mica slate soil.
9. Talcose slate soil.
10. Gneiss soil, common.
    Do. ferruginous.
11. Granite soil.
12. Sienite soil.
13. Porphyry soil.
14. Greenstone soil.

A few paragraphs of explanation will, I trust, render these varieties of soil recognizable.

In general, if any one wishes to know where to find them, let him look at the Geological Map that accompanies this report, and he may conclude that the different soils cover those portions of the surface that are represented as occupied by the rocks from which they are derived. There is one circumstance, however, that prevents us from considering the boundaries of the rock formations as perfectly coincident with those of the soils. Diluvial action has removed nearly all the loose covering of our rocks in a southerly direction; often several miles; and more or less mingled the soils from different formations. Hence, where one formation lies north or south of another on the map, we may conclude that the detritus of the most northerly one has been swept southerly, or southeasterly, for several miles beyond the boundaries of the rock; and in few cases does the dividing line between two formations so exactly coincide with the direction of the diluvial current, that there is no overlapping and intermingling of the soils.

With common alluvial soils—the result of deposition from rivers,—every intelligent man is familiar. They are of course formed by the comminution of every kind of rock over which the stream that produces them happens to pass. These soils, I apprehend, owe their value chiefly to the fine state to which their component parts are reduced. In Massachusetts our alluvia are frequently coarse and quite siliceous.

Peat alluvium is composed principally of vegetable matter, and ought rather to be regarded as a manure than a soil. I include in it all those swamps that abound in decomposing vegetable matter, whether actually converted into peat or not.

Diluvial Soil is the most heterogeneous and wide spread of all soils, and strictly speaking it embraces nearly all our soils except alluvium: for nearly all of them have been moved and comminuted by diluvial action. But where a formation is so extensive that this diluvial agency has not transported the detritus derived from it beyond its boundaries, the soil may be regarded as belonging to that formation; and this is the case over a large part of the state: so that it will not be necessary to regard very extensive districts

of our soils as diluvium. I have not done it when it is possible to refer them to any other formation.

The most common variety of diluvial soil, and the poorest of the soils, consists of rounded pebbles and coarse sand, accumulated in situations where no existing streams could have carried them. I now also regard all those beds of clay and sand which occur in the state, except the plastic clay of the southeastern part, as the result of the retiring diluvial waters; so that there will be an argillaceous and a sandy diluvial soil; such as occur extensively in the valley of Connecticut river, and which I formerly denominated the Newest Tertiary.

The tertiary soils are almost exactly like the two last described varieties of the diluvial, viz. argillaceous and sandy. Indeed, it is doubtful whether any character except position can distinguish them: nor is the distinction of any importance in a practical point of view. The tertiary soils occur only in a few limited districts, in Dukes, Barnstable and Plymouth counties: viz. wherever the plastic clay exists so near the surface, as to modify the superincumbent diluvial sand.

The sandstone soil is confined exclusively to the vicinity of Connecticut river. Most of the sandstone there is of a red color; some of it even a blood red; and its disintegration has produced a soil of the same aspect; so that even at a great distance, the redness is quite manifest. There is no soil that can easily be confounded with this, except some limited tracts of ferruginous gneiss soil in Worcester county, and of chocolate colored graywacke, and red compact feldspar, in the eastern part of the State. In a few towns, as in Granby, the sandstone soil is of a gray color, because the rock is gray beneath it.

The graywacke soil is confined to the eastern part of the State. Its color is mostly a deep brown; and it is capable of being made some of the best land in the State; as will be evident when I refer to Dorchester, Roxbury, Brookline, Newton, Cambridge, the Bridgewaters, Taunton, Middleborough, Dighton, Somerset, &c. for examples of its most perfect development. In some of these towns the rock is chiefly a coarse conglomerate or plum pudding stone; and as this contains more calcareous matter than the slaty varieties, and decomposes more readily, probably it furnishes the best soil found over this formation. The slaty varieties occur in Quincy, Newton, Charlestown, &c. In the southwest part of Attleborough, the slate is of a chocolate color, and this peculiar hue is imparted to the soil. The same color prevails in some other places; but not extensively enough to produce any striking patches of this variety of soil.

The group of rocks underlying this variety of soil is denominated *graywacke*, not because it has been proved to be identical with the graywacke of Eu-

rope; but because it seems analogous in composition and structure with the European rocks of that formation: and there is nothing yet discovered in regard to its position that proves its age to be different.

The tracts are very limited in Massachusetts, where well characterized argillaceous or roofing slate is fully developed: and hence we have but little genuine clay slate soil. Where it does occur, as in a few towns in Worcester and Middlesex counties, also in Bernardston, in Franklin county, it has the dark color of the slate; and is easily distiguished. It is capable of being made an excellent soil.

The limestone soil is confined to the county of Berkshire. I give it this name because it lies above limestone; not because it contains more of the salts of lime than other soils in the State. For to my surprise, I find that in general it does not. Much of it probably resulted from the disintegration of the mica and talcose slates that occur in large quantities along with the limestone in that county; and probably, also, the calcareous matter, which it did once contain, has been exhausted by cultivation. The magnesian limestone and the soil thence resulting, appeared to me more extensive in New Marlborough than in any other part of the county.

The mica slate soil, which occupies extensive regions in Massachusetts, as the Geological Map will show, is distinguished in appearance from the clay slate soil, chiefly by being of a lighter color. Yet since the two rocks pass into each other imperceptibly, so do these soils. And in the western part of Berkshire county, as well as in the mica slate region extending from Worcester to the mouth of Merrimack river, the mica slate approaches so near to argillaceous slate, that the soil above it might, without much error, be referred to the latter rock. Most of our mica slate soils are of a superior quality.

The talcose slate soil is rather limited, and not of the best quality; though it should be recollected that it occupies some of the highest parts of the State, and might at a lower level be more productive. The argillo-talcose slate soils of the Taconic range in Berkshire, are of a better quality. In appearance the mica slate and talcose slate soils can hardly be distinguished from each other; though in general the latter is of a lighter color and more sandy.

Gneiss soil occupies more surface than any other in the State: and were we to judge from its appearance, we should conclude it the poorest soil within our limits. In general, it is of a pale yellow color, and very sandy or gravelly. And, indeed, in many places it is very meagre and unproductive. But over a great part of Worcester county, for instance, it is of a very different character, being enriched probably by the potassa of the feldspar and mica in gneiss. The ferruginous gneiss soil contains so much peroxide of

iron, that in some towns, as West Brookfield, Sturbridge, Brimfield, Oakham, &c., it is of a perceptible red color when seen at a distance.

Since granite and gneiss are composed of the same ingredients, the soils which they produce will not differ. And in fact they do not in Massachusetts: so that probably there is little advantage in separating them.

Sienite differs from granite in taking hornblende into its composition, as well as being in general of a finer texture. The soil resulting from its decomposition is certainly more favorable to cultivation than that derived from common granite: as an example of which I may refer to nearly the whole of Essex county.

The compact feldspar, that forms the basis of porphyry, frequently contains an unusually large proportion of alumina, from 15 to 30 per cent. And although this is the hardest of the rocks around Boston, in many places it decomposes rapidly, and the resulting soil admits of high cultivation, as may be seen in Medford and Lynn.

The greenstone in the eastern part of the State is so intimately connected with sienite and porphyry, that the attempt to separate the soils resulting from them, is almost useless. Yet the structure of the greenstone is finer, and where it predominates, we find a good soil; as in Ipswich and Woburn. The greenstone associated with sandstone, near Connecticut river, has a more earthy aspect, and produces by decomposition a peculiar yet valuable soil, of a deep brown color, and abounding in iron. It is, however, but of limited extent.

Sir Humphrey Davy divides soils into Clayey, Loamy, Chalky, Gravelly, Sandy, Peaty or Mossy, Boggy and Heathy, and Moory: Chaptal makes a more simple division into Argillaceous, Calcareous, Siliceous and Sandy. These divisions are very convenient, and it is only for the sake of reference that I have adopted in their stead the geological classification described above.

### *System pursued in collecting Soils.*

In executing that part of my commission which relates to the analysis of soils, I found it very difficult to decide upon the best plan for collecting them. My object was not to examine the soils of particular farms, or towns; but rather to point out the composition and character of the different classes of soils in the State. I therefore concluded to visit the different rock formations; and where I found the soils above them well characterized, to select specimens, in sufficient numbers, and over a sufficiently wide extent, to afford a fair representation of the different sorts of soils. Whatever might be found to be the characters of these selected specimens, from any particular

formation, I thought might be regarded as the characters of the soil in general over that formation; and to determine its extent, it would be necessary only to consult the Geological Map, with the statements in mind that have been made respecting diluvial action. And it is chiefly this consideration that led me to prefer the geological classification of soils. On this plan it seemed to me unnecessary to designate the particular farms from which the specimens were obtained.—I took care, however, in all cases, except those hereafter mentioned, to select my specimens from a cultivated ploughed field; about half way between the subsoil and the surface; and in a spot where the vegetable fibres had nearly disappeared by decomposition. I avoided, also, in general, the vicinity of buildings; especially barns: as I did also those fields where the soil had become very factitious by high cultivation; or where it was very sterile through neglect of culture. I endeavored to select spots where a medium state of cultivation existed; because I conceived that these would present the fairest average examples of the capabilities of our soils. And as most of the specimens were collected towards the close of summer, I could judge from the crops growing upon the fields, where the soil was in a medium state of cultivation. In a few cases I have purposely or accidentally taken specimens either from very poor or very rich spots; but such examples will be pointed out, when I come to give details. Roots, undecomposed *manure*, and large pebbles, were as much as possible avoided: and before proceeding to an analysis, I separated all the roots and pebbles larger than a quarter of an inch, with a course sieve. For although such matters generally exert some, and often a great influence upon the cultivation, yet it seems to me that their chemical examination can add little or nothing to what experience has already taught on this subject.

The soils were collected in tin canisters, which were labeled on the spot. Afterwards the specimens were spread out and exposed for several days to a warm sun and dry air, so as to expel all the moisture which could be driven off by natural evaporation. They were then returned to the canisters, and a portion taken for the various analytical processes which were adopted. After this, the residue was put into white glass bottles, which were sealed, numbered, and deposited in the State collection, along with other substances, such as marls, clay, quick much marsh mud, ochre, &c. This arrangement makes the specimens easy to be examined by the eye, without the danger of waste by uncorking the bottles.

### *Leading Objects of the Analysis of Soils.*

The views that have been given as to the origin and nature of soils will enable us to make a threefold classification of their constituents. First, their

earthy and metallic ingredients, which are chiefly silicates: Secondly, the acids, alkalies, and salts, which exist originally in them, or are introduced by cultivation: and thirdly, the water and organic matter which they contain. The latter constitutes the principal nourishment of plants, derived from the soil; while the salts are necessary to prepare that nourishment to be taken up and assimilated by their delicate vessels. The earth serves as a basis of support for the plant, as a receptacle for the nourishment, and probably also, in connection with the roots, as a galvanic combination, for the development of those electrical agencies by which the food of plants is taken up and converted into vegetable matter.

By almost any method of analysis that can be adopted, the three leading objects above specified will be more or less combined. But as some of these methods have a chief reference to one of these points, and others to other points, it will be practicable, in the first place, to confine our attention mostly to the earthy constituents of soils; and in the second place, to examine more particularly their salts and organic matter.

### *Analysis of Soils by Sir Humphrey Davy's Method.*

The method of analyzing soils proposed by the distinguished English chemist, Sir Humphrey Davy, in his Agricultural Chemistry, has been almost universally regarded as the best that has been invented. It consists in first driving off the water of absorption by a heat of 300°: Secondly, in boiling the soil in water, and suffering the coarser parts to settle, which are regarded as silica; while the finer, or aluminous portion, is suspended in the water, and is poured off: Thirdly, in determining by muriatic acid, the amount of carbonate of lime, if any be present: Fourthly, in burning off the organic matter of the finer part of the soil: Fifthly, in boiling the remainder in sulphuric acid, in order to dissolve the alumina and oxide of iron: Sixthly, in ascertaining the amount of soluble salts in the water employed for lixivation. The French Chemist, Chaptal, proposes essentially the same plan, though he renders it much more simple, by omitting the most difficult part; that is, the solution of the alumina and iron by sulphuric acid. The high reputation of Davy's rules led me to attempt their application to nearly half the soils which I had collected in Massachusetts: and the results are contained in the Table which follows.

Before presenting any analytical results, however, I wish to state the circumstances under which this part of the survey has been conducted. In some of the larger States of the Union, where geological surveys have been commenced, one or more chemists are constantly employed in the laboratory.

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No such course was adopted in Massachusetts: but the surveyor was directed, in general terms, to make an analysis of the soils, in his commission for a re-examination of the State. The question then arose in my mind, whether it would be possible, while carrying forward the other parts of the survey, to make a sufficient number of analytical investigations to be of much use. It was obvious that the time which I could devote to the subject, would not permit me to perform very numerous analyses with the extreme care and multiplied repetitions which the precision of modern science demands, in order to employ the results in settling the atomic constitution of bodies. Yet it occurred to me, that the objects of the Government might be in a good measure accomplished, if the results were not of the extremely accurate character above described. By a variety of means, some of which are described in the subjoined note,* and by the most laborious and devoted attention to the subject, I have been able to present a great number of results, which I trust will be found sufficiently accurate for the purposes I had in view. I do not mean that the processes were not conducted with care; and that I did not repeat them. Very many of them have been repeated again and again; especially whenever there was reason to suspect any material error in the results. Nor do I mean to say, that none of these results are sufficiently accurate to form the basis of scientific reasoning. As to that point, scientific men can judge when they examine my analyses: But I do not offer my conclusions for such a purpose: and wish, as an act of justice to myself, to have it understood, that the standard by which my analyses ought to be tried, is that of their practical value in an economical, not in a scientific point of view.

The following Table exhibits the results of the analysis of 61 soils, selected from the different formations in the State. For convenience, they are all

* The arrangement by which I was enabled most successfully to facilitate the process of analysis, consisted in providing means for carrying on ten similiar processes together. I made ten compartments upon a table, each provided with apparatus for filtering and precipitation. Ten flasks and ten evaporating dishes were also numbered, as well as ten common crucibles, with a circular piece of sheet iron, pierced with ten holes, and numbered to receive the crucibles. An oven of sheet zinc, with double sides, was likewise fitted up so as to receive ten filters, and to admit a thermometer. The sand bath was also made large enough to admit the ten flasks. By this arrangement, all the important processes in the analysis of soils, by the methods of Sir H. Davy and Dr. Dana, except weighing, could be conducted together, and almost as rapidly as if only one had been carried on. Even the weighing was in this way much facilitated, as any one can easily conceive. I applied also, so far as it was possible, the same method in conducting analyses in a more accurate manner. I supplied myself with four or five platinum and silver crucibles, which being charged, their contents were either fused together in a charcoal fire, or in succession over a spirit lamp. This process was repeated until ten substances were obtained in a state of fusion. Afterwards the processes were conducted as above described; except that the ignition of the results was performed over the spirit lamp. It is easy to see how by this arrangement a great saving of time was made.

I would not forget to mention also, my indebtedness to the faithfulness and perseverance of my chemical assistant, Mr. Abraham Jenkins, Jr. of Barre.

reduced to the same standard, viz: 100 grains; and the small loss, which inevitably attends this mode of analysis, has been apportioned among the several ingredients.

| No. | NAME AND LOCALITY OF SOIL. | Water of Absorption. | Organic Matter | Siliceous Deposite from Water. | Aluminous Deposite from Water. | Salts soluble in Water. | Composition of the Aluminous Deposite. Silica. | Alumina. | Oxide of Iron |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil; Deerfield. | 3.0 | 5.5 | 29.8 | 61.7 | | 55.2 | 3.5 | 3.0 |
| 2 | do Northampton. | 3.4 | 5.1 | 32.8 | 58.5 | 0.20 | 51.7 | 3.4 | 3.4 |
| 3 | do Deerfield. | 2.0 | 4.5 | 43.2 | 50.3 | | 44.1 | 3.7 | 2.5 |
| 4 | do Northampton. | 3.0 | 3.0 | 74.8 | 19.0 | 0.15 | 16.2 | 1.3 | 1.5 |
| 5 | do Northfield. | 2 7 | 4.2 | 43.9 | 49.2 | | 44.0 | 2.4 | 2.8 |
| 6 | do Northampton. | 2.1 | 3.2 | 40.0 | 54.7 | | 51.0 | 1.7 | 2.0 |
| 7 | do West Springfield. | 1.3 | 5.0 | 67.9 | 25.4 | 0.20 | 21.6 | 1.2 | 2.6 |
| 8 | do Stockbridge. | 1.9 | 4.9 | 83.5 | 9.7 | | 7.4 | 1·3 | 1.0 |
| 9 | do Hadley. | 4 4 | 6.6 | 45.6 | 43.0 | 0.20 | 39.4 | 1.6 | 2.0 |
| 10 | do Sheffield. | 2.2 | 5.5 | 62.1 | 30.0 | 0.20 | 23.9 | 3.0 | 3·1 |
| 13 | Tertiary Soil, Argillaceous; Springfield. | 3.3 | 10.0 | 47.8 | 38.7 | 0.16 | 32.7 | 3.5 | 2.5 |
| 16 | do do Barnstable. | 2.6 | 9.4 | 47.2 | 40.8 | 0.05 | 29.8 | 6.7 | 4.3 |
| 18 | do Sandy; Wareham. | 1.2 | 0.4 | 98.4 | 0.0 | | | | |
| 19 | do do Springfield. | 1.7 | 2.7 | 92.8 | 4.8 | | 2.4 | 1.3 | 1.1 |
| 20 | do do Barnstable. | 1.0 | 0.2 | 98.3 | 0.5 | | | | |
| 21 | do do Gloucester, (Squam.) | 0.15 | 0.0 | 99.6 | 0.0 | 0.20 | | | |
| 23 | Sandstone Soil, red; Longmeadow. | 2.4 | 4.4 | 79.0 | 14.0 | 0.20 | 10.6 | 1.3 | 2.1 |
| 25 | do do West Springfield. | 2.6 | 6.1 | 50.5 | 40.4 | 0.38 | 32.6 | 4.2 | 3.6 |
| 26 | do grey; Granby. | 2.8 | 3.9 | 37.3 | 55.9 | 0.13 | 48.6 | 2.6 | 4.7 |
| 27 | Graywacke Soil, Conglomerate; Dorchester. | 3.0 | 7.8 | 61-7 | 27.5 | | 19.3 | 4.7 | 3.5 |
| 30 | do do Walpole. | 2.2 | 7.6 | 56.0 | 34·1 | 0.10 | 28.5 | 3.1 | 2.5 |
| 31 | do do Dighton. | 1.6 | 5.2 | 59.3 | 33.8 | 0.10 | | | |
| 32 | do Slaty; Middleborough. | 1.7 | 6.0 | 69.2 | 23.0 | 0.10 | 17.0 | 2.2 | 3.8 |
| 35 | do do Watertown. | 4.1 | 9.1 | 45.6 | 41.0 | 0.20 | 31.9 | 4.1 | 5.0 |
| 36 | do do Halifax. | 1.5 | 5.5 | 82.6 | 10.3 | 0.14 | 6.9 | 2.3 | 1.1 |
| 38 | do do Taunton | 2.0 | 6.0 | 76.4 | 15.5 | 0.10 | 11.1 | 2.8 | 1.6 |
| 40 | do do, red; Attleboro,' S. W. part. | 3.2 | 9.7 | 43.0 | 44.0 | 0.12 | 27.5 | 8.0 | 8.5 |
| 41 | Argillaceous Slate Soil; Lancaster. | 3.0 | 9.5 | 59.3 | 28.1 | 0.09 | 23.1 | 3.1 | 1.9 |
| 43 | do do Townsend. | 3.5 | 11.5 | 70.5 | 14.2 | 0.32 | 7.2 | 4.5 | 2.5 |
| 44 | Limestone Soil, Magnesian; New Marlborough. | 1.9 | 5.8 | 67.6 | 24.6 | 0.12 | 16.6 | 4.0 | 4.0 |
| 45 | do common; Lanesborough. | 2.5 | 7.5 | 61.3 | 28.5 | 0.20 | 17.0 | 4.5 | 7.0 |
| 47 | do do North Adams. | 1.4 | 5.1 | 73.9 | 19.5 | 0.14 | 13.5 | 3.5 | 2.5 |
| 50 | do do Pitsfield. | 4.0 | 9.0 | 63.7 | 23.2 | 0.10 | 16.2 | 4.0 | 3.0 |
| 51 | do do Sheffield. | 3.9 | 7.2 | 67.7 | 20.9 | 0.32 | 11.9 | 5.0 | 4.0 |
| 54 | Mica Slate Soil; Webster. | 2.8 | 10.4 | 51.2 | 35.5 | 0.14 | 27.9 | 5.4 | 2.2 |
| 56 | do Stockbridge mountain. | 3.1 | 7.4 | 59.7 | 29.7 | 0.10 | 19.7 | 4.7 | 5.3 |
| 58 | do Bradford. | 3.0 | 10.4 | 44.0 | 42.3 | 0.25 | 32.3 | 5.8 | 4.2 |
| 59 | do West Newbury. | 3.0 | 7.6 | 65.2 | 24.1 | 0.10 | 16.2 | 5.1 | 2.8 |
| 60 | do Methuen. | 1.4 | 4.0 | 83.0 | 11.6 | | 6.4 | 1.0 | 4.2 |
| 63 | do Conway. | 1.4 | 6.3 | 67.7 | 24.5 | 0.10 | 18.3 | 4.3 | 1.9 |
| 65 | Talcose Slate; Charlemont. | 2.5 | 6.0 | 72.0 | 19.4 | 0.08 | 12.7 | 1.9 | 4.8 |
| 67 | Talco-micaceous Slate Soil; Hancock. | 2.8 | 9.7 | 44.8 | 42.7 | | 30.4 | 7.6 | 4.7 |
| 70 | Gneiss Soil; Bolton. | 2.8 | 7.3 | 63.5 | 26.2 | 0.25 | 22.2 | 2.3 | 1.7 |
| 71 | do Uxbridge. | 2.5 | 7.0 | 37.8 | 52.5 | 0.19 | 44.8 | 4.3 | 3.4 |
| 77 | do Rutland. | 3.8 | 10.2 | 58.7 | 27.0 | 0.26 | 21.0 | 3.5 | 2 5 |
| 79 | do Royalston. | 4.0 | 9.0 | 67.6 | 19.3 | 0.14 | 14.9 | 3.2 | 1.2 |
| 89 | do Grafton. | 3.0 | 7.7 | 40.1 | 49.0 | 0.20 | 38.9 | 6.7 | 3 4 |
| 90 | do Brimfield | 2.1 | 6.9 | 70.9 | 20.0 | 0,10 | 15.9 | 2.9 | 1.2 |
| 93 | do Becket. | 4.0 | 9.0 | 64.6 | 22.0 | 0.40 | 16.6 | 3.4 | 2.0 |
| 96 | do Sturbridge. | 1.8 | 5.7 | 77.1 | 15.2 | 0.22 | 11.3 | 2.3 | 1.6 |
| 104 | Granite Soil; Andover. | 3.3 | 9.5 | 54.4 | 32.6 | 0.20 | 26.9 | 3.9 | 1.8 |
| 106 | Sienite Soil; Marblehead. | 3.7 | 8.9 | 61.5 | 25.8 | 0.10 | 20.0 | 2.3 | 3.5 |
| 108 | do Gloucester. | 1.7 | 4.8 | 80.0 | 13.4 | 0.13 | 9.6 | 2.1 | 1 7 |
| 109 | do Lexington. | 3.7 | 10.0 | 46.7 | 39.4 | 0.16 | 34.0 | 3.0 | 2.4 |
| 111 | do Newbury. | 3.5 | 7,5 | 60.1 | 28.8 | 0.12 | 22.2 | 4.4 | 2.2 |
| 112 | do Dedham. | 4.3 | 9.9 | 46.3 | 39.3 | 0.17 | 31.4 | 5.1 | 2.8 |
| 117 | do Marshfield. | 2.0 | 5.2 | 68.7 | 24.0 | 0.11 | 19.2 | 2.7 | 2.1 |
| 120 | Porphyry Soil; Medford. | 4.1 | 10.6 | 51.9 | 33.2 | 0.15 | 27.7 | 3.5 | 2.0 |
| 122 | do Lynn. | 4.0 | 8.5 | 46.4 | 40.8 | 0.30 | 34.6 | 3.7 | 2 5 |
| 124 | Greenstone Soil; Woburn. | 4.0 | 10.3 | 46.7 | 38.9 | 0.15 | 33.7 | 2.3 | 2.9 |
| 125 | do Deerfield. | 2.0 | 7.0 | 32.7 | 58.2 | 0.10 | 30.5 | 3.3 | 4.4 |

### *Explanation of the preceding Table with remarks.*

The numbers in the first column of the preceding table, denote the specimens of the soils deposited in the State collection: and the second column points out the name and locality.

However thoroughly soils are dried in the sun, a quantity of water still adheres to them, which cannot be entirely driven off, until they are heated to nearly 300° of Fahrenheit's thermometer; or to the point where paper begins to turn brown. This was the way in which the numbers in the third column were obtained, by heating 100 grains to that point and noting the loss of weight. Highly siliceous soils retain but very little of this water of absorption, while from highly aluminous ones, it is not all driven off by heating to 300°. The power of soils to retain water, however, depends much more upon the quantity and character of the organic matter which they contain, than upon their mineral composition, as I shall endeavor to show hereafter.

After driving off the water of absorption, the soil was heated to redness, and continued in that state until every thing combustible was burnt off. The loss of weight showed the quantity of organic matter; and thus the fourth column was formed.

The fourth column in the above table presents one fact worthy of notice. It seems that our alluvial soils, although deservedly celebrated, contain less of organic matter than almost any other in the State. The principles above suggested explain their fertility in consistency with this fact: but it shows us, if I mistake not, that such soils, if not constantly supplied with manures, either by the overflowing of rivers, or by the farmer, will be sooner exhausted than almost any others.

The numbers in the fifth and sixth columns were obtained in the following manner. One hundred grains of the soil were boiled a short time in a glass flask in water, and after cooling, this was agitated until the soil was all diffused through the water. As soon as the agitation of the water had ceased, it was poured off along with the finer parts of the soil that did not settle at once. The portion that remained usually consisted of siliceous sand, while that which was left suspended in the water, was much more aluminous, and constituted the finest and most important part of the soil. In the present instance, this deposite is in larger proportion than is usual in analysis, because it was poured off immediately after the agitation had ceased, under an impression that by waiting two or three minutes, as is usual, other and more important substances than silica may settle to the bottom of the vessel. Indeed, I found this to be the case in some instances when the light matter was

poured off immediately. Thus, the red sandstone soil, No 23, from Longmeadow, gave only 14 grains of aluminous matter, and 79 grains of siliceous. By digestion in acid, the 14 grains yielded only 1.3 gr. of alumina and 2.1 gr. oxide of iron. But by treating the 79 grains of siliceous matter in the same way, it produced 7.5 grains of alumina and 4 grains peroxide of iron. Such cases teach us that this mechanical separation of the siliceous and aluminous matter is not a little uncertain: although in general it must be confessed, that when the lighter part was poured off immediately, the remainder was chiefly siliceous sand.

It is not the object of this process however, to show us the quantity of silica and alumina in a soil: but rather the amount of finely divided matter. For the best soils are found, in general, to abound in such matter: although it may become excessive, rendering the soil impervious to air and moisture. This is a principal defect in highly argillaceous soils. But from the preceding table it appears, in my opinion, that the soils in Massachusetts are in general too coarse rather than too fine. Being derived chiefly from primitive rocks, they resist comminution and decomposition more than the secondary rocks. I am satisfied that the principal excellence of our alluvial soils depends more upon their finely divided state than any thing else: for, as I have already in part shown, and shall show farther in the sequel, they must yield in value in some important respects, to our upland soils. And even as to their fineness, they are much coarser than many of the rich alluvia of the Western States; though it may be doubted whether for most crops they are on this account the less valuable.

The term salt, in chemistry, has a much more extended meaning than in popular language. Thus common limestone (carbonate of lime) and gypsum (sulphate of lime) are properly denominated salts, as is also phosphate of lime and chloride of calcium (muriate of lime). All compounds of any acid with lime, magnesia, alumina, potassa, soda, &c. or of chlorine with their metallic bases are salts: and some of these are soluble and some insoluble in water. If any of the former exist in soils therefore, they will be dissolved, if the soil be boiled in water. And if afterwards this water be evaporated, the salt can be obtained in a dry state and weighed. This is the way in which column seventh was filled. Tests were also applied to the solutions, in order to ascertain the nature of these salts. Hydrocyanate of potassa, infusion of nutgalls, the chlorides of calcium and magnesium, and the carbonate of ammonia and phosphote of soda gave no precipitate in any instance. Hence I infer the absence of iron and the salts of magnesia. But nitrate of silver, baryta water, nitrate and acetate of baryta, and oxalate of ammonia, gave precipitates more or less abundant in every instance in which I tried them. I hence infer the presence of a sulphate, probably the sulphate of lime, in all

the soils of Massachusetts that I have examined, and I have no doubt but it exists in every one of our soils. The quantity given in the table, is probably much less than the truth, for the sulphate of lime is but slightly soluble in water, and the quantity of water which I employed, was too small to dissolve all that exists in 100 grains; or rather 200 grains, which was the quantity usually boiled. It was chiefly to ascertain the fact of its existence that the experiments were performed; since I had adopted a better method for ascertaining its quantity. This salt exists, also, probably in nearly all the springs, rivers, and ponds in the State. The great importance of gypsum, in the process of vegetation, furnishes a reason for its universal diffusion.

The remaining columns of the Table exhibit the composition of the aluminous deposite in the sixth column. That deposite was boiled two or three hours in sulphuric, or hydrochloric acid, and the alumina and iron were precipitated together by carbonate of ammonia, and afterwards separated by hydrate of potassa. The portion remaining undissolved by the acid, was considered as silica.

### *Insufficiency of this mode of Analysis.*

I might easily have proceeded farther with these analyses: but had I at the commencement the same opinion of the insufficiency of Davy's method, as I now have, I should not have proceeded even so far. So far as this method is mechanical, it is of value; since it enables any one, not skilled in the manipulations of the laboratory, to ascertain whether a soil is coarse, or in a finely divided state. But the chemistry of this method is very bad. In the first place, it does not profess to determine the amount of silica, alumina, iron, &c. in the entire soil, but only in its finely divided portion. Now I have already mentioned a case, in which the siliceous residuum (of No. 23.) yielded almost as large a per cent. of alumina and oxide of iron as the aluminous portion. And I shall soon mention numerous examples, in which accurate analysis of the whole soil shows a much larger per cent. of these ingredients than this method discovers. In the second place, this method does by no means give the relative proportion of the ingredients in a soil, especially of the silica and alumina; because the latter is soluble with difficulty in sulphuric acid. Being desirous of ascertaining what proportion of the alumina could be extracted by the direct action of acids, I selected seven of the soils given in the preceding table, and subjected the aluminous deposite, obtained in the manner that has been described, to thorough analysis by fusion with soda, in platinum crucibles. The results may be seen in the following Table.

| No. | Aluminous Deposite. | Alumina by Acids. | Alumina by Alkali. | Silica by Acids. | Silica by Alkali. | Alumina per cent. | |
|---|---|---|---|---|---|---|---|
| 2 | 58.5 | 3.4 | 17.6 | 51.0 | 37.5 | 30.1 | 30.9 Mean. |
| 40 | 44.0 | 8.0 | 11.8 | 27.5 | 23.7 | 26.8 | |
| 41 | 28.1 | 3.1 | 9.4 | 23.1 | 16.8 | 33.6 | |
| 47 | 19.5 | 3.5 | 6.3 | 13.5 | 10.7 | 32.3 | |
| 58 | 42.3 | 5.8 | 12.2 | 32.3 | 25.9 | 28.8 | |
| 89 | 49.0 | 6.7 | 14.9 | 38.9 | 30.7 | 30.4 | |
| 112 | 39.3 | 5.1 | 13.0 | 31.3 | 23.0 | 34.3 | |

The number of the soil in the state collection* is given in the first column of the above table: the amount of the aluminous deposite in the second; the alumina by boiling in acid, as given in the first table, in the third column; the alumina by fusion with carbonate of soda in the fourth column: the silica, after the action of acids, in the fifth: the silica by alkali in the sixth: and the per cent. of alumina by the same process in the last.

A mere glance at these results, if they are not very erroneous, shows us how extremely deficient are Davy's rules in this particular. It is true that a repetition of his process, with fresh sulphuric acid, would dissolve more alumina; and in this way a gradual approximation might be obtained towards the truth: but such repetitions would prove more laborious than the process by fusion with alkali, and thus defeat the very object this distinguished chemist had in view, viz. so to simplify the analysis of soils, that it might be performed by intelligent farmers, though not familiar with chemical manipulation.

But in the third place, I have been brought to the conclusion, that even if these rules should give accurately the proportion of the ingredients, they would be of little importance; because the fertility of soils depends but very little upon the proportion of their earthy ingredients: in other words, these may vary greatly, without affecting the fertility. Partly to ascertain how far this principle is true, and partly to determine more accurately what are the earthy constituents of the soils of Massachusetts, I have made several analyses of the different geological varieties by fusion with an alkali; the only method which can at all satisfy the chemist. In the first example no attempt was made to determine the presence or amount of lime and magnesia. 100 grains of a diluvial argillaceous soil from Plymouth contain,

* There are two series of numbers in the State Collection both commencing with unity. One series is confined entirely to those specimens that are contained in glass bottles, which amount to 227. The other series extends to more than 2500. To distinguish between the two series, whenever they are referred to, I shall annex the letter *b*, to those of the first series, except the soils, which amount to 152, and the marls, clays, marly clays, and muck sands, where it seems unnecessary.

| | |
|---|---|
| Water of Absorption. | 2.7 |
| Organic Matter. | 6.0 |
| Oxide of Iron. | 6.5 |
| Salts Soluble in Water. | 0.4 |
| Alumina. | 19.2 |
| Silica. | 65.2 |
| | 100.0 |

In the following examples, I directed my attention to a determination of the amount of silica, alumina, lime, and magnesia, in the entire soil; having previously driven off the water and organic matter by heat. The salts of lime were obtained by another process, which will be explained farther on; and are added here for the sake of giving a complete view of the composition of the soils. It will be seen that I have added, for the sake of comparison, four examples of some of the richest soils in Illinois and Ohio. For convenience, the results are reduced to a centessimal standard: although only 15 grains were usually employed in the analysis.

| NO. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Peroxide of Iron. | Carbonate of Lime. | Sulphate of Lime. | Phospate of Lime. | Lime. | Magnesia. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil, Deerfield. | 2.0 | 7.0 | 55.50 | 22.06 | 5.11 | | 2.00 | 0.90 | 2.18 | 2.60 | 1.23 |
| 18 | Diluvial Sand, Wareham. | 1.4 | 1.2 | 84.68 | 7.76 | 1.89 | | 0.40 | 0.40 | 2.32 | | |
| 23 | Red Sandstone Soil, L. Meadow | 4.2 | 3.6 | 65.45 | 16.45 | 5.07 | | 3.20 | 0.69 | 0.74 | 0.25 | 0.44 |
| 28 | Graywacke Soil, Roxbury. | 2.6 | 8.4 | 63.68 | 17.37 | 3.65 | | 2.30 | 1.46 | | 0.48 | 0.12 |
| 41 | Argil. Slate Soil, Lancaster. | 7.4 | 7.4 | 57.87 | 16.66 | 4.70 | | 4.69 | 0.96 | 0.59 | 0.44 | 0.04 |
| 46 | Limestone Soil, G. Barrington. | 2.0 | 6.0 | 69.92 | 12.22 | 5.63 | | 1.70 | 0.50 | 1.14 | 0.76 | 0.73 |
| 59 | Mica Slate Soil, W. Newbury. | 3.8 | 5.8 | 67.49 | 11.87 | 3.80 | | 3.50 | 1.00 | 1.09 | 1.08 | 0.57 |
| 64 | Talcose Slate Soil, Chester. | 2.6 | 4.6 | 68.01 | 14.10 | 2.57 | | 3.10 | 1.00 | | 2.82 | 1.20 |
| 81 | Gneiss Soil, Petersham. | 5.6 | 7.4 | 60.85 | 18.77 | 3.22 | | 2.40 | 0.40 | | 1.14 | 0.22 |
| 103 | Granite Soil, Duxbury. | 2.4 | 5.2 | 74.77 | 12.57 | 3.10 | | 0.80 | 0.70 | 0.11 | 0.67 | 0.28 |
| 109 | Sienite Soil, Lexington. | 4.0 | 9.8 | 65.00 | 13.11 | 4.00 | | 2.60 | 0.60 | | 0.52 | 0.37 |
| 120 | Porphyry Soil, Medford. | 2.8 | 12.4 | 59.78 | 16.38 | 3.54 | | 2.60 | 0.80 | 0.81 | 0.80 | 0.09 |
| 125 | Greenstone Soil, Deerfield. | 2.0 | 6.2 | 65.39 | 16.35 | 6.05 | 2.00 | 0.10 | 0.30 | 0.63 | 0.91 | 0.07 |
| 198 | Rushville, Illinois. | 6.3 | 9.9 | 63.35 | 15.60 | 5.57 | 1.50 | 3.40 | 0.60 | | 0.68 | |
| 199 | Sangamon Co. do. | 6.3 | 10.5 | 66.71 | 8.28 | 4.42 | 1.39 | 1.20 | 0.40 | | 0.56 | 0.33 |
| 200 | Lazelle Co. do. | 9.5 | 21.4 | 47.09 | 9.87 | 5.38 | 3.36 | 1.40 | 0.40 | | 1.68 | 0.58 |
| 201 | Sciota Valley, Ohio. | 5.3 | 11.2 | 62.64 | 9.18 | 5.46 | 2.80 | 2.10 | 0.90 | | trace | 0.48 |

The preceding Table hardly needs explanation: except to remark, that the column headed Lime, contains the excess of that substance, found by the process with alkali in some specimens, above the amount contained in the carbonate, sulphate, and phosphate. This excess probably existed in the soil either as a silicate or a geate.

For the sake of a more extensive comparison, I shall here quote a few analyses of soils that have been distinguished for their fertility. Most of them are European.

In the Second Report of Mr. Colman on the Agriculture of Massachusetts, Dr. S. L. Dana has given the analysis of a soil from Chelmsford, on the Merrimack River, which has produced a large crop of wheat for 20 years with only one failure. 100 parts contain

| | |
|---|---|
| Soluble Geine, | 3.9228 |
| Insoluble Geine, | 2.6142 |
| Sulphate of Lime, | .7060 |
| Phosphate of Lime, | .9082 |
| Silicates (Silica, alumina, iron, &c.) | 91.8485 |

No trace of carbonate of lime or of alkaline salts could be discovered.

In his third annual report on the geology of Maine, Dr. C. T. Jackson has given the following analysis of a soil from that State, which has produced 48 bushels of wheat per acre.

| | |
|---|---|
| Water, | 5.0 |
| Vegetable Matter, | 17.5 |
| Silica, | 54.2 |
| Alumina, | 10.6 |
| Sub Phosphate of Alumina, | 3.0 |
| Peroxide of Iron, | 7.0 |
| Oxide of Manganese, | 1.0 |
| Carbonate of Lime, | 1.5 |
| | 99.8 |

An excellent wheat soil from the County of Middlesex in England, was analyzed by Sir Humphry Davy, and gave in 100 parts,

| | |
|---|---|
| Siliceous Sand, | 60 |
| Finely divided matter, | 40 |

100 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 28 |
| Silica, | 32 |
| Alumina, | 29 |
| Organic Matter and Water, | 11 |

A very productive soil from the County of Somerset, gave

| | |
|---|---|
| Siliceous Sand, | 89 |
| Finely divided Matter, | 11 |

432 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 360 |
| Alumina, | 25 |
| Silica, | 20 |
| Oxide of Iron, | 8 |
| Organic and Saline Matter, | 19 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | |
|---|---|---|---|
| Ashes of wheat, | 48 Silica, | 37 Lime. | 15 Alumina. |
| " of oats, | 68 " | 26 " | 6 " |
| " of barley, | 69 " | 16 " | 15 " |
| " of rye, | 63 " | 21 " | 16 " |
| " of potatoes, | 4 " | 66 " | 30 " |
| " of red clover, | 37 " | 33 " | 30 " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an alumnious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

*Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

### *Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | | |
|---|---|---|---|---|
| " | 80 | Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " | 186 | do Sandisfield, | 2.80 | " |
| " | 113 | Sienite Soil, Wrentham, | 0.40 | " |
| " | 125 | Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

### *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

velopment of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell, to whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin.* More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they call it *Humin;* but Berzelius adopts the name of *Geine.* When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalies upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates,* most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity, and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analyzing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturalist. Those of Dr. Dana appear to me to be far more important; although essentially coinciding with those of European chemists. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and elegant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable It can affect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine: but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali;* and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest: magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates*, always more soluble than neutral salts. Soluble geine, therefore, includes the watery solution—the solid extract caused by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluble geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those alrea-

dy quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of the soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is composed wholly or chiefly, of one earth; or any soil, with excess of salt, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification:—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into "*silicates*;" by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphates have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphate of lime, than on its animal portion. Though the same plants growing in different soils are

found to yield variable quantities of the *salts* and earthy compounds, yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granitic rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the silicates are decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is chiefly *silicates*, using the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, or too clayey, may be modified by mixture; but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analyzing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

### *Rules of Analysis.*

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus, or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear: wash the grounds with 4 ounces boiling water: throw all on a double weighed filter, previously dried at the same temperature as was the soil (1); wash till colorless water returns. Mix all these liquors. It is a

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3 2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 32 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.5 | 0.6 | 93.8 | | | 2.58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1.4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5.4 | 5.3 | 1.0 | | 0.7 | 87 6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0 5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5 0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2 29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1 5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0 6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3 8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1.7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0 9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2,54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0 6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0 6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4 6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5 7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0 7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2 8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, - - - - - | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, - - - - - | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, - - - - - | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, - - - - - | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, - - - - - | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, - - - - - | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2.40 |
| 108 | do Gloucester, - - - - - | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, - - - - - | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, - - - - - | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, - - - - - | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, - - - - - | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, - - - - - | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, - - - - | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, - - - - - | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, - - - - - | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, - - - - - | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, - - - - - | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. - - | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, - - - - - | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, - - - - - | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, - - - - - | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, - - - - - | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, - - - - - | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, - - - - - | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 127 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 phos. lime, | | 3.3 phos. iron. | |
| " | Birch | 7.3 | " | 1.25 | " |
| " | Oak wood | 1.8 | " | | |
| " | Alder coal | 3.45 | " | 9.00 | " |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Candolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

*Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphaté of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. *(Third Report on the Geology of Maine, p. 150.)*

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxúriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c." London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 cz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates*, because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

*Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

*Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

| | |
|---|---|
| Water of Absorption. | 2.7 |
| Organic Matter. | 6.0 |
| Oxide of Iron. | 6.5 |
| Salts Soluble in Water. | 0.4 |
| Alumina. | 19.2 |
| Silica. | 65.2 |
| | 100.0 |

In the following examples, I directed my attention to a determination of the amount of silica, alumina, lime, and magnesia, in the entire soil; having previously driven off the water and organic matter by heat. The salts of lime were obtained by another process, which will be explained farther on; and are added here for the sake of giving a complete view of the composition of the soils. It will be seen that I have added, for the sake of comparison, four examples of some of the richest soils in Illinois and Ohio. For convenience, the results are reduced to a centessimal standard: although only 15 grains were usually employed in the analysis.

| NO. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Peroxide of Iron. | Carbonate of Lime. | Sulphate of Lime. | Phospate of Lime. | Lime. | Magnesia. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil, Deerfield. | 2.0 | 7.0 | 55.50 | 22.06 | 5.11 | | 2.00 | 0.90 | 2.18 | 2.00 | 1.23 |
| 18 | Diluvial Sand, Wareham. | 1.4 | 1.2 | 84.68 | 7.76 | 1.89 | | 0.40 | 0.40 | 2.32 | | |
| 23 | Red Sandstone Soil, L Meadow | 4.2 | 3.6 | 65.45 | 16.45 | 5.17 | | 3.20 | 0.60 | 0.74 | 0.25 | 0.44 |
| 28 | Graywacke Soil, Roxbury. | 2.6 | 8.4 | 63.68 | 17.37 | 3.65 | | 2.30 | 1.46 | | 0.48 | 0.12 |
| 41 | Argil. Slate Soil, Lancaster. | 7.4 | 7.4 | 57.87 | 16.66 | 4.70 | | 4.60 | 0.90 | 0.59 | 0.44 | 0.04 |
| 46 | Limestone Soil, G. Barrington. | 2.0 | 6.0 | 69.92 | 12.22 | 5.63 | | 1.70 | 0.50 | 1.14 | 0.76 | 0.73 |
| 59 | Mica Slate Soil, W. Newbury. | 3.8 | 5.8 | 67.49 | 11.87 | 3.80 | | 3.50 | 1.00 | 1.09 | 1.08 | 0.57 |
| 64 | Talcose Slate Soil, Chester. | 2.6 | 4.6 | 68.01 | 14.10 | 2.57 | | 3.10 | 1.00 | | 2.82 | 1.20 |
| 81 | Gneiss Soil, Petersham. | 5.6 | 7.4 | 60.85 | 18.77 | 3.22 | | 2.40 | 0.40 | | 1.14 | 0.22 |
| 103 | Granite Soil, Duxbury. | 2.4 | 5.2 | 74.77 | 12.57 | 3.10 | | 0.80 | 0.70 | 0.11 | 0.67 | 0.28 |
| 109 | Sienite Soil, Lexington. | 4.0 | 9.8 | 65.00 | 13.11 | 4.00 | | 2.60 | 0.60 | | 0.52 | 0.37 |
| 120 | Porphyry Soil, Medford. | 2.8 | 12.4 | 59.78 | 16.38 | 3.54 | | 2.60 | 0.80 | 0.81 | 0.80 | 0.09 |
| 125 | Greenstone Soil, Deerfield. | 2.0 | 6.2 | 65.39 | 16.35 | 6.05 | 2.00 | 0.10 | 0.30 | 0.63 | 0.91 | 0.07 |
| 198 | Rushville, Illinois. | 6.3 | 9.9 | 63.35 | 15.00 | 5.57 | 1.50 | 3.40 | 0.60 | | 0.68 | |
| 199 | Sangamon Co. do. | 6.3 | 10.5 | 66.71 | 8.28 | 4.42 | 1.39 | 1.20 | 0.40 | | 0.56 | 0.33 |
| 200 | Lazelle Co. do. | 9.5 | 21.4 | 47.09 | 9.87 | 5.38 | 3.30 | 1.40 | 0.40 | | 1.08 | 0.58 |
| 201 | Sciota Valley, Ohio. | 5.3 | 11.2 | 62.64 | 9.18 | 5.40 | 2.80 | 2.10 | 0.90 | | trace | 0.48 |

The preceding Table hardly needs explanation: except to remark, that the column headed Lime, contains the excess of that substance, found by the process with alkali in some specimens, above the amount contained in the carbonate, sulphate, and phosphate. This excess probably existed in the soil either as a silicate or a geate.

For the sake of a more extensive comparison, I shall here quote a few analyses of soils that have been distinguished for their fertility. Most of them are European.

In the Second Report of Mr. Colman on the Agriculture of Massachusetts, Dr. S. L. Dana has given the analysis of a soil from Chelmsford, on the Merrimack River, which has produced a large crop of wheat for 20 years with only one failure. 100 parts contain

| | |
|---|---|
| Soluble Geine, | 3.9228 |
| Insoluble Geine, | 2.6142 |
| Sulphate of Lime, | .7060 |
| Phosphate of Lime, | .9082 |
| Silicates (Silica, alumina, iron, &c.) | 91.8485 |

No trace of carbonate of lime or of alkaline salts could be discovered.

In his third annual report on the geology of Maine, Dr. C. T. Jackson has given the following analysis of a soil from that State, which has produced 48 bushels of wheat per acre.

| | |
|---|---|
| Water, | 5.0 |
| Vegetable Matter, | 17.5 |
| Silica, | 54.2 |
| Alumina, | 10.6 |
| Sub Phosphate of Alumina, | 3.0 |
| Peroxide of Iron, | 7.0 |
| Oxide of Manganese, | 1.0 |
| Carbonate of Lime, | 1.5 |
| | 99.8 |

An excellent wheat soil from the County of Middlesex in England, was analyzed by Sir Humphry Davy, and gave in 100 parts,

| | |
|---|---|
| Siliceous Sand, | 60 |
| Finely divided matter, | 40 |

100 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 28 |
| Silica, | 32 |
| Alumina, | 29 |
| Organic Matter and Water, | 11 |

A very productive soil from the County of Somerset, gave

| | |
|---|---|
| Siliceous Sand, | 89 |
| Finely divided Matter, | 11 |

432 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 360 |
| Alumina, | 25 |
| Silica, | 20 |
| Oxide of Iron, | 8 |
| Organic and Saline Matter, | 19 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | |
|---|---|---|---|
| Ashes of wheat, | 48 Silica, | 37 Lime. | 15 Alumina. |
| " of oats, | 68 " | 26 " | 6 " |
| " of barley, | 69 " | 16 " | 15 " |
| " of rye, | 63 " | 21 " | 16 " |
| " of potatoes, | 4 " | 66 " | 30 " |
| " of red clover, | 37 " | 33 " | 30 " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an aluminious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

*Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

### *Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | | |
|---|---|---|---|---|
| " | 80 | Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " | 186 | do Sandisfield, | 2.80 | " |
| " | 113 | Sienite Soil, Wrentham, | 0.40 | " |
| " | 125 | Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

### *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

velopment of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell, to whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin*. More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they call it *Humin;* but Berzelius adopts the name of *Geine*. When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalies upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates,* most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity, and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analyzing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturalist. Those of Dr. Dana appear to me to be far more important; although essentially coinciding with those of European chemists. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and elegant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable It can affect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine: but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali*; and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest: magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates*, always more soluble than neutral salts. Soluble geine, therefore, includes the watery solution—the solid extract caused by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluble geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those alrea-

dy quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of the soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is composed wholly or chiefly, of one earth; or any soil, with excess of salt, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification:—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into "*silicates*;" by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphates have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphate of lime, than on its animal portion. Though the same plants growing in different soils are

found to yield variable quantities of the *salts* and earthy compounds, yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granitic rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the silicates are decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is chiefly *silicates*, using the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, or too clayey, may be modified by mixture; but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analyzing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

### *Rules of Analysis.*

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus, or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear: wash the grounds with 4 ounces boiling water: throw all on a double weighed filter, previously dried at the same temperature as was the soil (1); wash till colorless water returns. Mix all these liquors. It is a

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3 2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 82 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.5 | 0.6 | 93.8 | | | 2·58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1,4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5.4 | 5.3 | 1.0 | | 0.7 | 87 6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0 5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2 29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1 5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3 8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1,7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0 9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2,54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0 6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0 6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4 6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5 7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0 7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2 40 |
| 108 | do Gloucester, | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, | 1.6 | 2 9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 127 | do New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 | phos. lime, | 3.3 | phos. iron. |
| " | Birch | 7.3 | " | 1.25 | " |
| " | Oak wood | 1.8 | " | | |
| " | Alder coal | 3.45 | " | 9.00 | " |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Çandolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86.6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. (*Third Report on the Geology of Maine, p.* 150.)

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxuriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c." London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol.* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

*Explanation of the preceding Table with remarks.*

The numbers in the first column of the preceding table, denote the specimens of the soils deposited in the State collection: and the second column points out the name and locality.

However thoroughly soils are dried in the sun, a quantity of water still adheres to them, which cannot be entirely driven off, until they are heated to nearly 300° of Fahrenheit's thermometer; or to the point where paper begins to turn brown. This was the way in which the numbers in the third column were obtained, by heating 100 grains to that point and noting the loss of weight. Highly siliceous soils retain but very little of this water of absorption, while from highly aluminous ones, it is not all driven off by heating to 300°. The power of soils to retain water, however, depends much more upon the quantity and character of the organic matter which they contain, than upon their mineral composition, as I shall endeavor to show hereafter.

After driving off the water of absorption, the soil was heated to redness, and continued in that state until every thing combustible was burnt off. The loss of weight showed the quantity of organic matter; and thus the fourth column was formed.

The fourth column in the above table presents one fact worthy of notice. It seems that our alluvial soils, although deservedly celebrated, contain less of organic matter than almost any other in the State. The principles above suggested explain their fertility in consistency with this fact: but it shows us, if I mistake not, that such soils, if not constantly supplied with manures, either by the overflowing of rivers, or by the farmer, will be sooner exhausted than almost any others.

The numbers in the fifth and sixth columns were obtained in the following manner. One hundred grains of the soil were boiled a short time in a glass flask in water, and after cooling, this was agitated until the soil was all diffused through the water. As soon as the agitation of the water had ceased, it was poured off along with the finer parts of the soil that did not settle at once. The portion that remained usually consisted of siliceous sand, while that which was left suspended in the water, was much more aluminous, and constituted the finest and most important part of the soil. In the present instance, this deposite is in larger proportion than is usual in analysis, because it was poured off immediately after the agitation had ceased, under an impression that by waiting two or three minutes, as is usual, other and more important substances than silica may settle to the bottom of the vessel. Indeed, I found this to be the case in some instances when the light matter was

poured off immediately. Thus, the red sandstone soil, No 23, from Longmeadow, gave only 14 grains of aluminous matter, and 79 grains of siliceous. By digestion in acid, the 14 grains yielded only 1.3 gr. of alumina and 2.1 gr. oxide of iron. But by treating the 79 grains of siliceous matter in the same way, it produced 7.5 grains of alumina and 4 grains peroxide of iron. Such cases teach us that this mechanical separation of the siliceous and aluminous matter is not a little uncertain: although in general it must be confessed, that when the lighter part was poured off immediately, the remainder was chiefly siliceous sand.

It is not the object of this process however, to show us the quantity of silica and alumina in a soil: but rather the amount of finely divided matter. For the best soils are found, in general, to abound in such matter: although it may become excessive, rendering the soil impervious to air and moisture. This is a principal defect in highly argillaceous soils. But from the preceding table it appears, in my opinion, that the soils in Massachusetts are in general too coarse rather than too fine. Being derived chiefly from primitive rocks, they resist comminution and decomposition more than the secondary rocks. I am satisfied that the principal excellence of our alluvial soils depends more upon their finely divided state than any thing else: for, as I have already in part shown, and shall show farther in the sequel, they must yield in value in some important respects, to our upland soils. And even as to their fineness, they are much coarser than many of the rich alluvia of the Western States; though it may be doubted whether for most crops they are on this account the less valuable.

The term salt, in chemistry, has a much more extended meaning than in popular language. Thus common limestone (carbonate of lime) and gypsum (sulphate of lime) are properly denominated salts, as is also phosphate of lime and chloride of calcium (muriate of lime). All compounds of any acid with lime, magnesia, alumina, potassa, soda, &c. or of chlorine with their metallic bases are salts: and some of these are soluble and some insoluble in water. If any of the former exist in soils therefore, they will be dissolved, if the soil be boiled in water. And if afterwards this water be evaporated, the salt can be obtained in a dry state and weighed. This is the way in which column seventh was filled. Tests were also applied to the solutions, in order to ascertain the nature of these salts. Hydrocyanate of potassa, infusion of nutgalls, the chlorides of calcium and magnesium, and the carbonate of ammonia and phosphote of soda gave no precipitate in any instance. Hence I infer the absence of iron and the salts of magnesia. But nitrate of silver, baryta water, nitrate and acetate of baryta, and oxalate of ammonia, gave precipitates more or less abundant in every instance in which I tried them. I hence infer the presence of a sulphate, probably the sulphate of lime, in all

the soils of Massachusetts that I have examined, and I have no doubt but it exists in every one of our soils. The quantity given in the table, is probably much less than the truth, for the sulphate of lime is but slightly soluble in water, and the quantity of water which I employed, was too small to dissolve all that exists in 100 grains; or rather 200 grains, which was the quantity usually boiled. It was chiefly to ascertain the fact of its existence that the experiments were performed; since I had adopted a better method for ascertaining its quantity. This salt exists, also, probably in nearly all the springs, rivers, and ponds in the State. The great importance of gypsum, in the process of vegetation, furnishes a reason for its universal diffusion.

The remaining columns of the Table exhibit the composition of the aluminous deposite in the sixth column. That deposite was boiled two or three hours in sulphuric, or hydrochloric acid, and the alumina and iron were precipitated together by carbonate of ammonia, and afterwards separated by hydrate of potassa. The portion remaining undissolved by the acid, was considered as silica.

### *Insufficiency of this mode of Analysis.*

I might easily have proceeded farther with these analyses: but had I at the commencement the same opinion of the insufficiency of Davy's method, as I now have, I should not have proceeded even so far. So far as this method is mechanical, it is of value; since it enables any one, not skilled in the manipulations of the laboratory, to ascertain whether a soil is coarse, or in a finely divided state. But the chemistry of this method is very bad. In the first place, it does not profess to determine the amount of silica, alumina, iron, &c. in the entire soil, but only in its finely divided portion. Now I have already mentioned a case, in which the siliceous residuum (of No. 23.) yielded almost as large a per cent. of alumina and oxide of iron as the aluminous portion. And I shall soon mention numerous examples, in which accurate analysis of the whole soil shows a much larger per cent. of these ingredients than this method discovers. In the second place, this method does by no means give the relative proportion of the ingredients in a soil, especially of the silica and alumina; because the latter is soluble with difficulty in sulphuric acid. Being desirous of ascertaining what proportion of the alumina could be extracted by the direct action of acids, I selected seven of the soils given in the preceding table, and subjected the aluminous deposite, obtained in the manner that has been described, to thorough analysis by fusion with soda, in platinum crucibles. The results may be seen in the following Table.

| No. | Aluminous Deposite. | Alumina by Acids. | Alumina by Alkali. | Silica by Acids. | Silica by Alkali. | Alumina per cent. | |
|---|---|---|---|---|---|---|---|
| 2 | 58.5 | 3.4 | 17.6 | 51.0 | 37.5 | 30.1 | |
| 40 | 44.0 | 8.0 | 11.8 | 27.5 | 23.7 | 26.8 | |
| 41 | 28.1 | 3.1 | 9.4 | 23.1 | 16.8 | 33.6 | |
| 47 | 19.5 | 3.5 | 6.3 | 13.5 | 10.7 | 32.3 | 30.9 Mean. |
| 58 | 42.3 | 5.8 | 12.2 | 32.3 | 25.9 | 28.8 | |
| 89 | 49.0 | 6.7 | 14.9 | 38.9 | 30.7 | 30.4 | |
| 112 | 39.3 | 5.1 | 13.0 | 31.3 | 23.0 | 34.3 | |

The number of the soil in the state collection* is given in the first column of the above table: the amount of the aluminous deposite in the second; the alumina by boiling in acid, as given in the first table, in the third column; the alumina by fusion with carbonate of soda in the fourth column: the silica, after the action of acids, in the fifth: the silica by alkali in the sixth: and the per cent. of alumina by the same process in the last.

A mere glance at these results, if they are not very erroneous, shows us how extremely deficient are Davy's rules in this particular. It is true that a repetition of his process, with fresh sulphuric acid, would dissolve more alumina; and in this way a gradual approximation might be obtained towards the truth: but such repetitions would prove more laborious than the process by fusion with alkali, and thus defeat the very object this distinguished chemist had in view, viz. so to simplify the analysis of soils, that it might be performed by intelligent farmers, though not familiar with chemical manipulation.

But in the third place, I have been brought to the conclusion, that even if these rules should give accurately the proportion of the ingredients, they would be of little importance; because the fertility of soils depends but very little upon the proportion of their earthy ingredients: in other words, these may vary greatly, without affecting the fertility. Partly to ascertain how far this principle is true, and partly to determine more accurately what are the earthy constituents of the soils of Massachusetts, I have made several analyses of the different geological varieties by fusion with an alkali; the only method which can at all satisfy the chemist. In the first example no attempt was made to determine the presence or amount of lime and magnesia. 100 grains of a diluvial argillaceous soil from Plymouth contain,

* There are two series of numbers in the State Collection both commencing with unity. One series is confined entirely to those specimens that are contained in glass bottles, which amount to 227. The other series extends to more than 2500. To distinguish between the two series, whenever they are referred to, I shall annex the letter *b*, to those of the first series, except the soils, which amount to 152, and the marls, clays, marly clays, and muck sands, where it seems unnecessary.

| | |
|---|---|
| Water of Absorption. | 2.7 |
| Organic Matter. | 6.0 |
| Oxide of Iron. | 6.5 |
| Salts Soluble in Water. | 0.4 |
| Alumina. | 19.2 |
| Silica. | 65.2 |
| | 100.0 |

In the following examples, I directed my attention to a determination of the amount of silica, alumina, lime, and magnesia, in the entire soil; having previously driven off the water and organic matter by heat. The salts of lime were obtained by another process, which will be explained farther on; and are added here for the sake of giving a complete view of the composition of the soils. It will be seen that I have added, for the sake of comparison, four examples of some of the richest soils in Illinois and Ohio. For convenience, the results are reduced to a centessimal standard: although only 15 grains were usually employed in the analysis.

| NO. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Peroxide of Iron. | Carbonate of Lime. | Sulphate of Lime. | Phospate of Lime. | Lime. | Magnesia. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvial Soil, Deerfield. | 2.0 | 7.0 | 55.50 | 22.66 | 5.11 | | 2.00 | 0.90 | 2.18 | 2.00 | 1.23 |
| 18 | Diluvial Sand, Wareham. | 1.4 | 1.2 | 84.68 | 7.76 | 1.89 | | 0.40 | 0.40 | 2.32 | | |
| 23 | Red Sandstone Soil, L. Meadow | 4.2 | 3.6 | 65.45 | 16.45 | 5.67 | | 3.20 | 0.66 | 0.74 | 0.25 | 0.44 |
| 28 | Graywacke Soil, Roxbury. | 2.6 | 8.4 | 63.68 | 17.37 | 3.65 | | 2.30 | 1.46 | | 0.48 | 0.12 |
| 41 | Argil. Slate Soil, Lancaster. | 7.4 | 7.4 | 57.87 | 16.66 | 4.70 | | 4.60 | 0.96 | 0.59 | 0.44 | 0.04 |
| 46 | Limestone Soil, G. Barrington. | 2.0 | 6.0 | 69.92 | 12.22 | 5.63 | | 1.70 | 0.50 | 1.14 | 0.76 | 0.73 |
| 59 | Mica Slate Soil, W. Newbury. | 3.8 | 5.8 | 67.49 | 11.87 | 3.80 | | 3.50 | 1.00 | 1.69 | 1.08 | 0.57 |
| 64 | Talcose Slate Soil, Chester. | 2.6 | 4.6 | 68.01 | 14.10 | 2.57 | | 3.10 | 1.00 | | 2.82 | 1.20 |
| 81 | Gneiss Soil, Petersham. | 5.6 | 7.4 | 60.85 | 18.77 | 3.22 | | 2.40 | 0.40 | | 1.14 | 0.22 |
| 103 | Granite Soil, Duxbury. | 2.4 | 5.2 | 74.77 | 12.57 | 3.10 | | 0.80 | 0.70 | 0.11 | 0.67 | 0.28 |
| 109 | Sienite Soil, Lexington. | 4.0 | 9.8 | 65.00 | 13.11 | 4.00 | | 2.60 | 0.60 | | 0.52 | 0.37 |
| 120 | Porphyry Soil, Medford. | 2.8 | 12.4 | 59.78 | 16.38 | 3.54 | | 2.60 | 0.80 | 0.81 | 0.80 | 0.09 |
| 125 | Greenstone Soil, Deerfield. | 2.0 | 6.2 | 65.39 | 16.35 | 6.05 | 2.00 | 0.10 | 0.30 | 0.63 | 0.91 | 0.07 |
| 198 | Rushville, Illinois. | 6.3 | 9.9 | 63.35 | 15.60 | 5.57 | 1.50 | 3.40 | 0.60 | | 0.68 | |
| 199 | Sangamon Co. do. | 6.3 | 10.5 | 66.71 | 8.28 | 4.42 | 1.39 | 1.20 | 0.40 | | 0.56 | 0.33 |
| 200 | Lazelle Co. do. | 9.5 | 21.4 | 47.09 | 9.87 | 5.38 | 3.36 | 1.40 | 0.40 | | 1.68 | 0.58 |
| 201 | Sciota Valley, Ohio. | 5.3 | 11.2 | 62.64 | 9.18 | 5.40 | 2.80 | 2.10 | 0.90 | | trace | 0.48 |

The preceding Table hardly needs explanation: except to remark, that the column headed Lime, contains the excess of that substance, found by the process with alkali in some specimens, above the amount contained in the carbonate, sulphate, and phosphate. This excess probably existed in the soil either as a silicate or a geate.

For the sake of a more extensive comparison, I shall here quote a few analyses of soils that have been distinguished for their fertility. Most of them are European.

In the Second Report of Mr. Colman on the Agriculture of Massachusetts, Dr. S. L. Dana has given the analysis of a soil from Chelmsford, on the Merrimack River, which has produced a large crop of wheat for 20 years with only one failure. 100 parts contain

| | |
|---|---|
| Soluble Geine, | 3.9228 |
| Insoluble Geine, | 2.6142 |
| Sulphate of Lime, | .7060 |
| Phosphate of Lime, | .9082 |
| Silicates (Silica, alumina, iron, &c.) | 91.8485 |

No trace of carbonate of lime or of alkaline salts could be discovered.

In his third annual report on the geology of Maine, Dr. C. T. Jackson has given the following analysis of a soil from that State, which has produced 48 bushels of wheat per acre.

| | |
|---|---|
| Water, | 5.0 |
| Vegetable Matter, | 17.5 |
| Silica, | 54.2 |
| Alumina, | 10.6 |
| Sub Phosphate of Alumina, | 3.0 |
| Peroxide of Iron, | 7.0 |
| Oxide of Manganese, | 1.0 |
| Carbonate of Lime, | 1.5 |
| | 99.8 |

An excellent wheat soil from the County of Middlesex in England, was analyzed by Sir Humphry Davy, and gave in 100 parts,

| | |
|---|---|
| Siliceous Sand, | 60 |
| Finely divided matter, | 40 |

100 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 28 |
| Silica, | 32 |
| Alumina, | 29 |
| Organic Matter and Water, | 11 |

A very productive soil from the County of Somerset, gave

| | |
|---|---|
| Siliceous Sand, | 89 |
| Finely divided Matter, | 11 |

432 parts of the latter gave

| | |
|---|---|
| Carbonate of Lime, | 360 |
| Alumina, | 25 |
| Silica, | 20 |
| Oxide of Iron, | 8 |
| Organic and Saline Matter, | 19 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | |
|---|---|---|---|
| Ashes of wheat, | 48 Silica, | 37 Lime. | 15 Alumina. |
| " of oats, | 68 " | 26 " | 6 " |
| " of barley, | 69 " | 16 " | 15 " |
| " of rye, | 63 " | 21 " | 16 " |
| " of potatoes, | 4 " | 66 " | 30 " |
| " of red clover, | 37 " | 33 " | 30 " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an alumnious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

*Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

*Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | |
|---|---|---|---|
| " | 80 Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " | 186 do Sandisfield, | 2.80 | " |
| " | 113 Sienite Soil, Wrentham, | 0.40 | " |
| " | 125 Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

## *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

velopment of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell, to whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin*. More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they call it *Humin;* but Berzelius adopts the name of *Geine*. When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalies upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates*, most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity, and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analyzing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturalist. Those of Dr. Dana appear to me to be far more important; although essentially coinciding with those of European chemists. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and elegant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable It can affect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine: but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali;* and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest: magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates,* always more soluble than neutral salts. Soluble geine, therefore, includes the watery solution—the solid extract caused by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluble geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those alrea-

dy quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of the soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is composed wholly or chiefly, of one earth; or any soil, with excess of salt, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification:—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into "*silicates*;" by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphates have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphate of lime, than on its animal portion. Though the same plants growing in different soils are

found to yield variable quantities of the *salts* and earthy compounds, yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granitic rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the silicates are decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is chiefly *silicates*, using the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, or too clayey, may be modified by mixture; but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analyzing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

## *Rules of Analysis.*

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus, or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear: wash the grounds with 4 ounces boiling water: throw all on a double weighed filter, previously dried at the same temperature as was the soil (1); wash till colorless water returns. Mix all these liquors. It is a

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3 2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 82 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1,1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.6 | 0.6 | 93.8 | | | 2.58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1.4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5.4 | 5.3 | 1.0 | | 0.7 | 87.6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0.5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2.29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1.5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3.8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1.7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0.9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2.54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0.6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0.6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4.6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5.7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0.7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, - - - - - | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, - - - - - | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, - - - - - | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, - - - - - | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, - - - - - | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, - - - - - | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2.40 |
| 108 | do Gloucester, - - - - - | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, - - - - - | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, - - - - - | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, - - - - - | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, - - - - - | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, - - - - - | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, - - - - | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, - - - - - | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, - - - - - | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, - - - - - | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, - - - - - | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. - - | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, - - - - - | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, - - - - - | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, - - - - - | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, - - - - | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, - - - - - | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, - - - - - | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 127 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

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ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 | phos. lime, | 3.3 | phos. iron. |
| " | Birch | 7.3 | " | 1.25 | " |
| " | Oak wood | 1.8 | " | | |
| " | Alder coal | 3.45 | " | 9.00 | " |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Çandolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. (*Third Report on the Geology of Maine, p.* 150.)

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxuriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c." London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 cz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates*, because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

### *Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

### *Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

## *Experiments on the Retaining Power of Soils.*

| No. | Loss of 200 grs. in 3 1-2 hours June. 25 | Gain at night | Loss in 2 1-2 hours June 26. | Additional loss in 4 hours July 1. |
|---|---|---|---|---|
| 1 | 100 | 5 | 100 | 6 |
| 2 | 96 | 7 | 98 | 8 |
| 3 | 93 | 6 | 99 | 7 |
| 4 | 100 | 7 | 105 | 3 |
| 5 | 102 | 8 | 103 | 6 |
| 6 | 100 | 5 | 103 | 4 |
| 7 | 99 | 8 | 101 | 2 |
| 8 | 103 | 8 | 105 | 4 |
| 9 | 99 | 9 | 101 | 8 |
| 10 | 102 | 9 | 105 | 5 |
| 11 | 100 | 7 | 105 | 3 |
| 12 | 101 | 7 | 97 | 10 |
| 13 | 100 | 7 | 101 | 8 |
| 14 | 102 | 8 | 102 | 8 |
| 15 | 101 | 5 | 103 | |
| 16 | 101 | 7 | 104 | |
| 17 | 101 | 7 | 104 | |
| 18 | 100 | 5 | 108 | |
| 19 | 95 | 6 | 107 | |
| 20 | 99 | 4 | 102 | |
| 21 | 101 | 6 | 109 | |
| 22 | 100 | 4 | 104 | |
| 23 | 88 | 5 | 109 | |
| 24 | 101 | 6 | 104 | |
| 25 | 101 | 4 | 108 | |
| 26 | 103 | | | |
| 27 | 102 | 9 | 101 | 8 |
| 28 | 101 | 7 | 104 | 5 |
| 29 | 100 | 7 | 97 | 12 |
| 30 | 102 | 10 | 105 | 5 |
| 31 | 101 | 10 | 108 | 4 |
| 32 | 98 | 11 | 108 | 5 |
| 33 | 102 | 12 | 103 | 9 |
| 34 | 100 | 11 | 103 | 9 |
| 35 | 82 | 14 | 102 | 14 |
| 36 | 101 | 9 | 104 | 6 |
| 37 | 97 | 12 | 108 | 4 |
| 38 | 101 | 12 | 107 | 5 |
| 39 | 101 | 11 | 106 | 7 |
| 40 | 101 | 13 | 102 | 13 |
| 41 | 92 | 13 | 105 | |
| 42 | 101 | | 104 | |
| 43 | 106 | | 112 | |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional loss in 4 hours. |
|---|---|---|---|---|
| 44 | 105 | 17 (?) | 112 | |
| 45 | 106 | 14 | 111 | |
| 46 | 103 | 13 | 100 | |
| 47 | 100 | 9 | 106 | |
| 48 | 102 | 9 | 100 | |
| 49 | 103 | 11 | 111 | |
| 50 | 102 | 8 | 105 | |
| 51 | 102 | 11 | 105 | 8 |
| 52 | 102 | 13 | 104 | 9 |
| 53 | 102 | 12 | 103 | 10 |
| 54 | 103 | 13 | 103 | 11 |
| 55 | 103 | 10 | 101 | 12 |
| 56 | 101 | 7 | 100 | 9 |
| 57 | 102 | 9 | 106 | |
| 58 | 104 | 15 | 105 | |
| 59 | 100 | 12 | 103 | |
| 60 | 102 | 8 | 108 | |
| 61 | 102 | 9 | 104 | |
| 62 | 101 | 8 | 100 | 4 |
| 63 | 103 | 14 | 108 | 5 |
| 64 | 104 | | 108 | 4 |
| 65 | 105 | 17 (?) | 105 | 9 |
| 66 | 114 | 13 | 107 | 6 |
| 67 | 104 | 12 | 108 | 4 |
| 68 | 96 | 5 | 110 | |
| 69 | 107 | 15 | 109 | 1 |
| 70 | 106 | 12 | 106 | 2 |
| 71 | 104 | 11 | 106 | 3 |
| 72 | 104 | 9 | 107 | 0 |
| 73 | 109 | 13 | 104 | 1 |
| 74 | 104 | 7 | 91 | 14 |
| 75 | 99 | 7 | 93 | 12 |
| 76 | 101 | 9 | 97 | 10 |
| 77 | 101 | 10 | 101 | 5 |
| 78 | 102 | 9 | 105 | 1 |
| 79 | 100 | 9 | 102 | 5 |
| 80 | 102 | 12 | 111 | 1 |
| 81 | 101 | 13 | 111 | 10 |
| 82 | 101 | 5 | 95 | |
| 83 | 104 | 9 | 107 | |
| 84 | 106 | 10 | 104 | |
| 85 | 106 | 8 | 104 | |
| 86 | 103 | 6 | 102 | |
| 87 | 109 | 13 | 104 | |
| 88 | | 11 | 105 | |
| 89 | | 14 | 106 | 5 |
| 90 | | 12 | 108 | 1 |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional Loss in 4 hours. |
|---|---|---|---|---|
| 91 | 108 | 18 | 109 | 3 |
| 92 | 100 | 8 | 105 | 5 |
| 93 | 102 | 12 | 108 | 5 |
| 94 | 100 | 4 | 103 | 3 |
| 95 | 104 | 7 | 103 | 1 |
| 96 | 103 | | 102 | 1 |
| 97 | 102 | 11 | 110 | 2 |
| 98 | 103 | 12 | 109 | 3 |
| 99 | 102 | 12 | 109 | 3 |
| 100 | 101 | 11 | 106 | 5 |
| 101 | 103 | 10 | 110 | |
| 102 | 101 | 8 | 108 | |
| 103 | 101 | 9 | 110 | |
| 104 | 102 | 10 | 105 | |
| 105 | 102 | 8 | 109 | |
| 106 | 101 | 6 | 109 | |
| 107 | 102 | 9 | 110 | |
| 108 | 101 | 10 | 108 | |
| 109 | 103 | 10 | 105 | |
| 110 | 104 | 10 | 105 | |
| 111 | 101 | 4 | 98 | 9 |
| 112 | 102 | 8 | 101 | 9 |
| 113 | 100 | 3 | 100 | 6 |
| 114 | 101 | 5 | 105 | 1 |
| 115 | 102 | 4 | 99 | 6 |
| 116 | 101 | 3 | 100 | 14 |
| 117 | | | 102 | 4 |
| 118 | 100 | 0 | 99 | |
| 119 | 102 | 4 | 100 | |
| 120 | 102 | 3 | 101 | |
| 121 | 103 | 2 | 100 | |
| 122 | 103 | 2 | 102 | |
| 123 | | | 104 | 8 |
| 124 | 106 | 13 | 104 | 8 |
| 125 | 101 | 1 | 100 | 0 |
| 126 | | | 92 | 3 |
| 127 | 102 | 8 | 105 | 3 |
| 128 | | | 107 | 1 |
| 129 | 103 | 9 | 106 | 2 |
| 130 | 103 | 9 | 104 | 2 |
| 139 | | | 107 | 3 |
| 143 | | | 102 | 4 |
| 146 | 94 | 2 | 107 | 5 |
| 148 | 86 | 3 | 89 | 26 |

All the numbers in the above table over 125, belong to specimens of clay, muck sand, or marl; all of which will be described in other parts of my Re-

port. The results exhibit nothing of importance on which to remark, except perhaps that the specimen of marl (No. 148) appears to possess the strongest retaining power of all the substances tried: and this fact may suggest to us one of the causes that render marls valuable upon land. It will be seen, in the second column, that though only 100 grains of water were added, more than that quantity was usually given off in the course of 3 1-2 hours. This fact led me to expose the soils only 2 1-2 hours the next day; yet even then, more than, 100 grains were usually given off, because of the quantity of moisture absorbed during the night. At the third trial, whose results are given in the last column, I determined not to add any water, and to expose the plates a longer time, and since the last portions of water are always driven off with the most difficulty, I suspect that this last column exhibits better than the others, the relative power of the different soils to retain water in time of drought. I regret, therefore, that an accident has prevented this column from being complete.

### *Power of Soils to absorb Oxygen from the Atmosphere.*

In the excellent paper by Prof. Schubler on the Physical Properties of Soils, referred to on page 55, I find numerous experiments and remarks, not only upon the power of soils to absorb and retain water, but also oxygen gas and heat; as well as their electrical and other relations of importance. But I have room to notice only a few of the new and interesting views which he has presented. *See Journal of the English Agricultural Society, Vol 1 p.* 177. *Lond.* 1839.

Humboldt first pointed out the power of soils to absorb oxygen from the atmosphere: but his views were contradicted: yet they seem now fully established by Schubler. The following Table shows the amount of oxygen absorbed in 30 days, from fifteen cubic inches of air, by 1000 grains of the different soils named. In a dry state they absorbed none.

| | | | |
|---|---|---|---|
| Siliceous Sand, | 1.6 | 0.24 | 0.10 |
| Calcareous Sand, | 5.6 | 0.84 | 0.35 |
| Gypsum Powder, | 2.7 | 0.40 | 0.17 |
| Sandy Clay, | 9.3 | 1.39 | 0.59 |
| Loamy Clay, | 11.0 | 1.65 | 0.70 |
| Stiff Clay or Brick Earth, | 13.6 | 2.04 | 0.86 |
| Grey pure Clay, | 15.3 | 2.29 | 0.97 |
| Fine Lime, | 10.8 | 1.92 | 0.69 |
| Magnesia, | 17.0 | 2.66 | 1.08 |
| Humus, (Geine,) | 20.3 | 3.04 | 1.29 |
| Garden Mould, | 18.0 | 2.60 | 1.10 |
| Arable Soil, | 16.2 | 2.43 | 1.03 |
| Slaty Marl. | 11.0 | 1.65 | 0.70 |

**It appears from this Table, that Humus or Geine, absorbs more oxygen than any other soil: And Prof. Schubler says, that it enters into chemical combination with the geine, giving it a higher degree of oxygenation; and that some carbonic acid also is produced. Whereas no chemical union is formed between the other soils and the oxygen absorbed. Here then, we see another mode in which that wonderful substance, geine, acts as a fertilizer; viz. by furnishing carbonic acid and oxygen.**

### *Galvanic and Electrical Relations of the Soils.*

According to the same writer, the pure earths, such as sand, lime, magnesia and gypsum, when dry are non-conductors of electricity: but the clays and compound clayey earths are imperfect conductors. All the earths, when oblong dry pieces of them are scraped with a knife, develope negative electricity.

When solutions of Humus—that is, the salts of geine—are exposed to a current of galvanic electricity, decomposition immediately results. The geine collects around the positive pole, while the earths, or alkalies, collect around the negative pole. Do not these facts tend to confirm the views of Dr. Dana respecting the mode in which geine is taken up by the roots of plants; viz. by their forming galvanic combinations with the salts and earths in the soil, whereby the geine and the oxides are decomposed? Do they not, also, strengthen his opinion that geine is a distinct substance, which acts the part of an acid? If it be not a definite chemical compound, how could it be separated and go to the positive pole, by galvanism?

This paper of Prof. Schubler is certainly an important contribution to Agricultural Chemistry; and I regret that it did not fall under my notice, or rather, that it had not been published, when I was prosecuting experiments upon the soils of Massachusetts.

### *Specific Gravities.*

The last column in the general Table, contains the specific gravities of a large part of the soils; that is, their weight as compared with distilled water. In general it will be seen that the most sandy soils are the heaviest; those containing the most geine, the lightest. In the absence of a better method, this character might be employed to determine the amount of organic matter in a soil. But to obtain the specific gravities of soils, cannot be regarded as a matter of much importance; though the results may be of value in the researches of the chemist.

### *Theoretical Characteristics of the different geological varieties of Soils.*

Knowing what simple minerals constitute the different rocks, and what is the composition of those minerals, we can predict what ingredients will exist, and what ones will predominate, in the soils derived from those rocks. Where a soil is derived from quartz rock, or siliceous sandstone, we should expect that silica would greatly predominate, but where argillaceous slate forms the foundation of the soil, alumina will abound. We should expect a large proportion of lime in soils underlaid by limestone: though from causes already explained, analysis does not always verify this anticipation. In soils derived from granite, gneiss, mica slate and those sandstones abounding in fragments of feldspar and mica, we might expect to find potassa, or its salts, because this substance abounds in those minerals. In porphyry soils, for the same reason, soda might be expected: also magnesia in talcose slate soils:

and the single analysis of such a soil by fusion, given on a previous page, corresponds to this prediction. Since iron abounds in all the rocks, we should not expect beforehand to find it peculiarly abundant in any variety of soil.

As to the existence or predominance of silica, alumina, iron, lime and magnesia, in a soil, analysis, as already pointed out, will enable us to determine this point; and, indeed, in respect to most of these ingredients, mere inspection is sufficient for all practical purposes: and from the tables of analyses that have been given, these characteristics, as they exist in the soils of Massachusetts, can easily be determined. But in respect to the alkalies, potassa and soda, which unquestionably exert an important influence upon vegetation where they exist, the case is quite different. As these exist in the feldspar and mica of soils, they are perfectly insoluble in water, but when set free by decomposition, even though converted into salts, they become easily soluble in water: and the consequence is, that rains soon carry them away. We should hence expect the chemist would rarely find them, even in traces. But as some chemists are of opinion that the salts of the alkalies do exist, widely disseminated in soils, I felt desirous of settling the point in relation to the soils of Massachusetts. I selected specimens of nearly every variety of soil in the Government collection, and having boiled 200 or 300 grains for several hours in snow water, until the quantity was rather small, I filtered; and to the solution added a small quantity of a solution of nut-galls. Had there been the minutest quantity of alkali present, the solution would have assumed a greenish tinge: but in no instance was this the case. Hence I infer the absence of alkali, and of alkaline salts. The soils thus tested were Nos. 9, 14, 29, 48, 62, 71, 82, 110, 121, and 124.

From such facts, however, I do not infer the absence of potassa and soda in every form from our soils; but only in a soluble state. On the other hand, it is almost certain, that in many of our soils they must exist in considerable quantity, and I doubt not but they exert an important influence upon cultivation. I impute the productiveness of many of our gneiss, granite, and sienite soils, to these substances. But I am inclined to adopt the opinion of Dr. Dana; who supposes that the rootlets of plants, by means of galvanic agency, have the power to extract alkali from the particles of feldspar and mica in the soil.

If these views are correct, it follows that it can be of little importance for the chemist to determine the precise amount of potassa or soda that may exist in the undecomposed feldspar or mica of a soil. For if the soil have resulted from the disintegration of rock that contains feldspar, he may be sure that alkali is present: But whether it will be of any use:—that is, whether it can be extracted from the soil by the plants, will depend upon the degree of comminution in the soil, and probably upon other circum-

stances not yet fully understood. That such salts as the sulphate of potassa may be found in some peculiar soils, is very probable; and their detection by analysis would be important; but with my present views, I anticipate that the search for them in the soils of New England generally will be in vain.

Such considerations cannot but lead the chemist to enquire, whether other principles, as important as the alkalies, may not exist in soils in such a state that they escape the notice of the analyst; or which he cannot detect in such a state as to afford much aid to practical agriculture. If so, perhaps it may partly explain why careful analysis has accomplished less for agriculture than had been anticipated; and that such is the fact, I am compelled to admit. I do not mean that analysis has been of no service to the farmer. In some instances it has pointed out to him particular substances in his land, that were beneficial or injurious; of which he would otherwise have been ignorant; and in all cases analyses form important materials for improving the theory of agricultural chemistry: which is certainly yet far from perfect. But probably some have been led to suppose, that the chemist, by analyzing their soil, would be able at once to inform them what ingredient might be added to insure fertility. This would imply a degree of perfection in agricultural chemistry to which I think the science cannot yet lay claim. To be sure, the analyst can often suggest the application of ingredients which will probably be beneficial. But the causes on which the growth of plants depends are too complicated, and as yet too imperfectly understood, to permit his recommendations to be infallible. And this leads me to express the opinion, that were a chemist to be employed in making experiments upon the manner in which geine and the salts in soils are taken up by vegetation; as well as upon the best mode of converting soluble into insoluble geine; and to analyze plants in their different stages of growth; very important results might reasonably be expected. The experiments which the farmer makes, that bear upon these points, (and a multitude of such experiments are made every year,) are performed as it were at random, without those fixed principles to guide him, which an accurate knowledge of chemistry would furnish; and hence it is only as it were by chance that any useful results follow.

### *General Conclusions.*

Having as I hope, by the preceding remarks, prevented the indulgence of unreasonable expectations from the examinations which I have made of the soils of Massachusetts, I proceed to state the most important conclusions to which those investigations have conducted me.

First: there is in general too small a supply of calcareous matter in our soils: that is, of lime.

The second great desideratum is an additional supply of geine, or the food of plants.

Hence, thirdly, the great object of the agricultural chemist should be, to discover new supplies of both these substances; and to suggest means for their proper and successful application by the farmer.

These conclusions early forced themselves upon my attention; and all my subsequent researches have served to confirm them. Hence, therefore, I made it my constant endeavor, to discover and examine the character and extent of every deposite that would yield either geine or calcareous matter. I shall now proceed to give the results of my efforts. I shall begin with lime. For although it cannot perhaps be regarded so important as geine, yet in common manures, the farmer possesses a store of the latter, which he knows how to apply. But with the exception of Berkshire County, Massachusetts is very deficient in calcareous matter: and the few spots where it may be found have as yet scarcely begun to excite any attention.

## I. CALCAREOUS MATTER IN MASSACHUSETTS.

### 1. *Marls.*

No form of calcareous matter is so valuable in agriculture as rich marl. This term, however, has been till recently very loosely applied; often meaning nothing more than loose clay, entirely destitute of lime. But all accurate writers now understand it to mean a friable mixture of lime and clay; although the term is extended to beds of calcareous shells that are somewhat hard. Till within a few years, this substance has been neglected in our country; but its remarkable effects in some of our middle and southern states, have awakened the public attention; and it is now sought after with no small avidity. From the nature of our rocks, I had no hope of finding rich marls in any other part of the State, except the County of Berkshire. From that part of the State, many years ago, I had seen a specimen that appeared very rich. I prepared therefore to go in search of the bed from which it was taken; and by the directions of Professor Dewey, I found it in Pittsfield, near the east part of the village, on the borders and in the bottom of a pond covering several acres. It seemed to me very probable that similar beds must occur in other parts of that County where limestone prevails. My search was soon rewarded by the discovery of an extensive bed in the northwest part of Stockbridge on land of Mr. Buck; whose thickness was about

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. *(Third Report on the Geology of Maine, p. 150.)*

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3.2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 82 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.5 | 0.6 | 93.8 | | | 2·58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1,4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5,4 | 5.3 | 1.0 | | 0.7 | 87 6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0.5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2 29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1 5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3 8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1,7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0 9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2,54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0 6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0 6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4 6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5 7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0 7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, - - - - - | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, - - - - - | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, - - - - - | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, - - - - - | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, - - - - - | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, - - - - - | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2.40 |
| 108 | do Gloucester, - - - - - | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, - - - - - | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, - - - - - | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, - - - - - | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, - - - - - | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, - - - - - | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, - - - - | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, - - - - - | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, - - - - - | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, - - - - - | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, - - - - - | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. - - | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, - - - - - | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, - - - - - | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, - - - - - | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, - - - - | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, - - - - - | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, - - - - - | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 127 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old methcd of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

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ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 | phos. lime, | 3.3 | phos. iron. | |
| " | Birch | 7.3 | " | 1.25 | " | |
| " | Oak wood | 1.8 | " | | | |
| " | Alder coal | 3.45 | " | 9.00 | " | |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Çandolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. (*Third Report on the Geology of Maine*, p. 150.)

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxuriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c." London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol.* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 oz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates*, because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

### *Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

### *Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

## *Experiments on the Retaining Power of Soils.*

| No. | Loss of 200 grs. in 3 1-2 hours June. 25 | Gain at night | Loss in 2 1-2 hours June 26. | Additional loss in 4 hours July 1. |
|---|---|---|---|---|
| 1 | 100 | 5 | 100 | 6 |
| 2 | 96 | 7 | 98 | 8 |
| 3 | 93 | 6 | 99 | 7 |
| 4 | 100 | 7 | 105 | 3 |
| 5 | 102 | 8 | 103 | 6 |
| 6 | 100 | 5 | 103 | 4 |
| 7 | 99 | 8 | 101 | 2 |
| 8 | 103 | 8 | 105 | 4 |
| 9 | 99 | 9 | 101 | 8 |
| 10 | 102 | 9 | 105 | 5 |
| 11 | 100 | 7 | 105 | 3 |
| 12 | 101 | 7 | 97 | 10 |
| 13 | 100 | 7 | 101 | 8 |
| 14 | 102 | 8 | 102 | 8 |
| 15 | 101 | 5 | 103 | |
| 16 | 101 | 7 | 104 | |
| 17 | 101 | 7 | 104 | |
| 18 | 100 | 5 | 108 | |
| 19 | 95 | 6 | 107 | |
| 20 | 99 | 4 | 102 | |
| 21 | 101 | 6 | 109 | |
| 22 | 100 | 4 | 104 | |
| 23 | 88 | 5 | 109 | |
| 24 | 101 | 6 | 104 | |
| 25 | 101 | 4 | 108 | |
| 26 | 103 | | | |
| 27 | 102 | 9 | 101 | 8 |
| 28 | 101 | 7 | 104 | 5 |
| 29 | 100 | 7 | 97 | 12 |
| 30 | 102 | 10 | 105 | 5 |
| 31 | 101 | 10 | 108 | 4 |
| 32 | 98 | 11 | 108 | 5 |
| 33 | 102 | 12 | 103 | 9 |
| 34 | 100 | 11 | 103 | 9 |
| 35 | 82 | 14 | 102 | 14 |
| 36 | 101 | 9 | 104 | 6 |
| 37 | 97 | 12 | 108 | 4 |
| 38 | 101 | 12 | 107 | 5 |
| 39 | 101 | 11 | 106 | 7 |
| 40 | 101 | 13 | 102 | 13 |
| 41 | 92 | 13 | 105 | |
| 42 | 101 | | 104 | |
| 43 | 106 | | 112 | |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional loss in 4 hours. |
|---|---|---|---|---|
| 44 | 105 | 17 (?) | 112 | |
| 45 | 106 | 14 | 111 | |
| 46 | 103 | 13 | 100 | |
| 47 | 100 | 9 | 106 | |
| 48 | 102 | 9 | 100 | |
| 49 | 103 | 11 | 111 | |
| 50 | 102 | 8 | 105 | |
| 51 | 102 | 11 | 105 | 8 |
| 52 | 102 | 13 | 104 | 9 |
| 53 | 102 | 12 | 103 | 10 |
| 54 | 103 | 13 | 103 | 11 |
| 55 | 103 | 10 | 101 | 12 |
| 56 | 101 | 7 | 100 | 9 |
| 57 | 102 | 9 | 106 | |
| 58 | 104 | 15 | 105 | |
| 59 | 100 | 12 | 103 | |
| 60 | 102 | 8 | 108 | |
| 61 | 102 | 9 | 104 | |
| 62 | 101 | 8 | 100 | 4 |
| 63 | 103 | 14 | 108 | 5 |
| 64 | 104 | | 108 | 4 |
| 65 | 105 | 17 (?) | 105 | 9 |
| 66 | 114 | 13 | 107 | 6 |
| 67 | 104 | 12 | 108 | 4 |
| 68 | 96 | 5 | 110 | |
| 69 | 107 | 15 | 109 | 1 |
| 70 | 106 | 12 | 106 | 2 |
| 71 | 104 | 11 | 106 | 3 |
| 72 | 104 | 9 | 107 | 0 |
| 73 | 109 | 13 | 104 | 1 |
| 74 | 104 | 7 | 91 | 14 |
| 75 | 99 | 7 | 93 | 12 |
| 76 | 101 | 9 | 97 | 10 |
| 77 | 101 | 10 | 101 | 5 |
| 78 | 102 | 9 | 105 | 1 |
| 79 | 100 | 9 | 102 | 5 |
| 80 | 102 | 12 | 111 | 1 |
| 81 | 101 | 13 | 111 | 10 |
| 82 | 101 | 5 | 95 | |
| 83 | 104 | 9 | 107 | |
| 84 | 106 | 10 | 104 | |
| 85 | 106 | 8 | 104 | |
| 86 | 103 | 6 | 102 | |
| 87 | 109 | 13 | 104 | |
| 88 | | 11 | 105 | |
| 89 | | 14 | 106 | 5 |
| 90 | | 12 | 108 | 1 |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional Loss in 4 hours. |
|---|---|---|---|---|
| 91 | 108 | 18 | 109 | 3 |
| 92 | 100 | 8 | 105 | 5 |
| 93 | 102 | 12 | 108 | 5 |
| 94 | 100 | 4 | 103 | 3 |
| 95 | 104 | 7 | 103 | 1 |
| 96 | 103 | | 102 | 1 |
| 97 | 102 | 11 | 110 | 2 |
| 98 | 103 | 12 | 109 | 3 |
| 99 | 102 | 12 | 109 | 3 |
| 100 | 101 | 11 | 106 | 5 |
| 101 | 103 | 10 | 110 | |
| 102 | 101 | 8 | 108 | |
| 103 | 101 | 9 | 110 | |
| 104 | 102 | 10 | 105 | |
| 105 | 102 | 8 | 109 | |
| 106 | 101 | 6 | 109 | |
| 107 | 102 | 9 | 110 | |
| 108 | 101 | 10 | 108 | |
| 109 | 103 | 10 | 105 | |
| 110 | 104 | 10 | 105 | |
| 111 | 101 | 4 | 98 | 9 |
| 112 | 102 | 8 | 101 | 9 |
| 113 | 100 | 3 | 100 | 6 |
| 114 | 101 | 5 | 105 | 1 |
| 115 | 102 | 4 | 99 | 6 |
| 116 | 101 | 3 | 100 | 14 |
| 117 | | | 102 | 4 |
| 118 | 100 | 0 | 99 | |
| 119 | 102 | 4 | 100 | |
| 120 | 102 | 3 | 101 | |
| 121 | 103 | 2 | 100 | |
| 122 | 103 | 2 | 102 | |
| 123 | | | 104 | 8 |
| 124 | 106 | 13 | 104 | 8 |
| 125 | 101 | 1 | 100 | 0 |
| 126 | | | 92 | 3 |
| 127 | 102 | 8 | 105 | 3 |
| 128 | | | 107 | 1 |
| 129 | 103 | 9 | 106 | 2 |
| 130 | 103 | 9 | 104 | 2 |
| 139 | | | 107 | 3 |
| 143 | | | 102 | 4 |
| 146 | 94 | 2 | 107 | 5 |
| 148 | 86 | 3 | 89 | 26 |

All the numbers in the above table over 125, belong to specimens of clay, muck sand, or marl; all of which will be described in other parts of my Re-

port. The results exhibit nothing of importance on which to remark, except perhaps that the specimen of marl (No. 148) appears to possess the strongest retaining power of all the substances tried: and this fact may suggest to us one of the causes that render marls valuable upon land. It will be seen, in the second column, that though only 100 grains of water were added, more than that quantity was usually given off in the course of 3 1-2 hours. This fact led me to expose the soils only 2 1-2 hours the next day; yet even then, more than, 100 grains were usually given off, because of the quantity of moisture absorbed during the night. At the third trial, whose results are given in the last column, I determined not to add any water, and to expose the plates a longer time, and since the last portions of water are always driven off with the most difficulty, I suspect that this last column exhibits better than the others, the relative power of the different soils to retain water in time of drought. I regret, therefore, that an accident has prevented this column from being complete.

## *Power of Soils to absorb Oxygen from the Atmosphere.*

In the excellent paper by Prof. Schubler on the Physical Properties of Soils, referred to on page 55, I find numerous experiments and remarks, not only upon the power of soils to absorb and retain water, but also oxygen gas and heat; as well as their electrical and other relations of importance. But I have room to notice only a few of the new and interesting views which he has presented. *See Journal of the English Agricultural Society, Vol 1 p.* 177. *Lond.* 1839.

Humboldt first pointed out the power of soils to absorb oxygen from the atmosphere: but his views were contradicted: yet they seem now fully established by Schubler. The following Table shows the amount of oxygen absorbed in 30 days, from fifteen cubic inches of air, by 1000 grains of the different soils named. In a dry state they absorbed none.

| | | | |
|---|---|---|---|
| Siliceous Sand, | 1.6 | 0.24 | 0.10 |
| Calcareous Sand, | 5.6 | 0.84 | 0.35 |
| Gypsum Powder, | 2.7 | 0.40 | 0.17 |
| Sandy Clay, | 9.3 | 1.39 | 0.59 |
| Loamy Clay, | 11.0 | 1.65 | 0.70 |
| Stiff Clay or Brick Earth, | 13.6 | 2.04 | 0.86 |
| Grey pure Clay, | 15.3 | 2.29 | 0.97 |
| Fine Lime, | 10.8 | 1.92 | 0.69 |
| Magnesia, | 17.0 | 2.66 | 1.08 |
| Humus, (Geine,) | 20.3 | 3.04 | 1.29 |
| Garden Mould, | 18.0 | 2.60 | 1.10 |
| Arable Soil, | 16.2 | 2.43 | 1.03 |
| Slaty Marl. | 11.0 | 1.65 | 0.70 |

It appears from this Table, that Humus or Geine, absorbs more oxygen than any other soil: And Prof. Schubler says, that it enters into chemical combination with the geine, giving it a higher degree of oxygenation; and that some carbonic acid also is produced. Whereas no chemical union is formed between the other soils and the oxygen absorbed. Here then, we see another mode in which that wonderful substance, geine, acts as a fertilizer; viz. by furnishing carbonic acid and oxygen.

### *Galvanic and Electrical Relations of the Soils.*

According to the same writer, the pure earths, such as sand, lime, magnesia and gypsum, when dry are non-conductors of electricity: but the clays and compound clayey earths are imperfect conductors. All the earths, when oblong dry pieces of them are scraped with a knife, develope negative electricity.

When solutions of Humus—that is, the salts of geine—are exposed to a current of galvanic electricity, decomposition immediately results. The geine collects around the positive pole, while the earths, or alkalies, collect around the negative pole. Do not these facts tend to confirm the views of Dr. Dana respecting the mode in which geine is taken up by the roots of plants; viz. by their forming galvanic combinations with the salts and earths in the soil, whereby the geine and the oxides are decomposed? Do they not, also, strengthen his opinion that geine is a distinct substance, which acts the part of an acid? If it be not a definite chemical compound, how could it be separated and go to the positive pole, by galvanism?

This paper of Prof. Schubler is certainly an important contribution to Agricultural Chemistry; and I regret that it did not fall under my notice, or rather, that it had not been published, when I was prosecuting experiments upon the soils of Massachusetts.

### *Specific Gravities.*

The last column in the general Table, contains the specific gravities of a large part of the soils; that is, their weight as compared with distilled water. In general it will be seen that the most sandy soils are the heaviest; those containing the most geine, the lightest. In the absence of a better method, this character might be employed to determine the amount of organic matter in a soil. But to obtain the specific gravities of soils, cannot be regarded as a matter of much importance; though the results may be of value in the researches of the chemist.

### *Theoretical Characteristics of the different geological varieties of Soils.*

Knowing what simple minerals constitute the different rocks, and what is the composition of those minerals, we can predict what ingredients will exist, and what ones will predominate, in the soils derived from those rocks. Where a soil is derived from quartz rock, or siliceous sandstone, we should expect that silica would greatly predominate, but where argillaceous slate forms the foundation of the soil, alumina will abound. We should expect a large proportion of lime in soils underlaid by limestone: though from causes already explained, analysis does not always verify this anticipation. In soils derived from granite, gneiss, mica slate and those sandstones abounding in fragments of feldspar and mica, we might expect to find potassa, or its salts, because this substance abounds in those minerals. In porphyry soils, for the same reason, soda might be expected: also magnesia in talcose slate soils:

and the single analysis of such a soil by fusion, given on a previous page, corresponds to this prediction. Since iron abounds in all the rocks, we should not expect beforehand to find it peculiarly abundant in any variety of soil.

As to the existence or predominance of silica, alumina, iron, lime and magnesia, in a soil, analysis, as already pointed out, will enable us to determine this point; and, indeed, in respect to most of these ingredients, mere inspection is sufficient for all practical purposes: and from the tables of analyses that have been given, these characteristics, as they exist in the soils of Massachusetts, can easily be determined. But in respect to the alkalies, potassa and soda, which unquestionably exert an important influence upon vegetation where they exist, the case is quite different. As these exist in the feldspar and mica of soils, they are perfectly insoluble in water, but when set free by decomposition, even though converted into salts, they become easily soluble in water: and the consequence is, that rains soon carry them away. We should hence expect the chemist would rarely find them, even in traces. But as some chemists are of opinion that the salts of the alkalies do exist, widely disseminated in soils, I felt desirous of settling the point in relation to the soils of Massachusetts. I selected specimens of nearly every variety of soil in the Government collection, and having boiled 200 or 300 grains for several hours in snow water, until the quantity was rather small, I filtered; and to the solution added a small quantity of a solution of nut-galls. Had there been the minutest quantity of alkali present, the solution would have assumed a greenish tinge: but in no instance was this the case. Hence I infer the absence of alkali, and of alkaline salts. The soils thus tested were Nos. 9, 14, 29, 48, 62, 71, 82, 110, 121, and 124.

From such facts, however, I do not infer the absence of potassa and soda in every form from our soils; but only in a soluble state. On the other hand, it is almost certain, that in many of our soils they must exist in considerable quantity, and I doubt not but they exert an important influence upon cultivation. I impute the productiveness of many of our gneiss, granite, and sienite soils, to these substances. But I am inclined to adopt the opinion of Dr. Dana; who supposes that the rootlets of plants, by means of galvanic agency, have the power to extract alkali from the particles of feldspar and mica in the soil.

If these views are correct, it follows that it can be of little importance for the chemist to determine the precise amount of potassa or soda that may exist in the undecomposed feldspar or mica of a soil. For if the soil have resulted from the disintegration of rock that contains feldspar, he may be sure that alkali is present: But whether it will be of any use:—that is, whether it can be extracted from the soil by the plants, will depend upon the degree of comminution in the soil, and probably upon other circum-

stances not yet fully understood. That such salts as the sulphate of potassa may be found in some peculiar soils, is very probable; and their detection by analysis would be important; but with my present views, I anticipate that the search for them in the soils of New England generally will be in vain.

Such considerations cannot but lead the chemist to enquire, whether other principles, as important as the alkalies, may not exist in soils in such a state that they escape the notice of the analyst; or which he cannot detect in such a state as to afford much aid to practical agriculture. If so, perhaps it may partly explain why careful analysis has accomplished less for agriculture than had been anticipated; and that such is the fact, I am compelled to admit. I do not mean that analysis has been of no service to the farmer. In some instances it has pointed out to him particular substances in his land, that were beneficial or injurious; of which he would otherwise have been ignorant; and in all cases analyses form important materials for improving the theory of agricultural chemistry: which is certainly yet far from perfect. But probably some have been led to suppose, that the chemist, by analyzing their soil, would be able at once to inform them what ingredient might be added to insure fertility. This would imply a degree of perfection in agricultural chemistry to which I think the science cannot yet lay claim. To be sure, the analyst can often suggest the application of ingredients which will probably be beneficial. But the causes on which the growth of plants depends are too complicated, and as yet too imperfectly understood, to permit his recommendations to be infallible. And this leads me to express the opinion, that were a chemist to be employed in making experiments upon the manner in which geine and the salts in soils are taken up by vegetation; as well as upon the best mode of converting soluble into insoluble geine; and to analyze plants in their different stages of growth; very important results might reasonably be expected. The experiments which the farmer makes, that bear upon these points, (and a multitude of such experiments are made every year,) are performed as it were at random, without those fixed principles to guide him, which an accurate knowledge of chemistry would furnish; and hence it is only as it were by chance that any useful results follow.

### *General Conclusions.*

Having as I hope, by the preceding remarks, prevented the indulgence of unreasonable expectations from the examinations which I have made of the soils of Massachusetts, I proceed to state the most important conclusions to which those investigations have conducted me.

First: there is in general too small a supply of calcareous matter in our soils: that is, of lime.

The second great desideratum is an additional supply of geine, or the food of plants.

Hence, thirdly, the great object of the agricultural chemist should be, to discover new supplies of both these substances; and to suggest means for their proper and successful application by the farmer.

These conclusions early forced themselves upon my attention; and all my subsequent researches have served to confirm them. Hence, therefore, I made it my constant endeavor, to discover and examine the character and extent of every deposite that would yield either geine or calcareous matter. I shall now proceed to give the results of my efforts. I shall begin with lime. For although it cannot perhaps be regarded so important as geine, yet in common manures, the farmer possesses a store of the latter, which he knows how to apply. But with the exception of Berkshire County, Massachusetts is very deficient in calcareous matter: and the few spots where it may be found have as yet scarcely begun to excite any attention.

## I. CALCAREOUS MATTER IN MASSACHUSETTS.

### 1. *Marls.*

No form of calcareous matter is so valuable in agriculture as rich marl. This term, however, has been till recently very loosely applied; often meaning nothing more than loose clay, entirely destitute of lime. But all accurate writers now understand it to mean a friable mixture of lime and clay; although the term is extended to beds of calcareous shells that are somewhat hard. Till within a few years, this substance has been neglected in our country; but its remarkable effects in some of our middle and southern states, have awakened the public attention; and it is now sought after with no small avidity. From the nature of our rocks, I had no hope of finding rich marls in any other part of the State, except the County of Berkshire. From that part of the State, many years ago, I had seen a specimen that appeared very rich. I prepared therefore to go in search of the bed from which it was taken; and by the directions of Professor Dewey, I found it in Pittsfield, near the east part of the village, on the borders and in the bottom of a pond covering several acres. It seemed to me very probable that similar beds must occur in other parts of that County where limestone prevails. My search was soon rewarded by the discovery of an extensive bed in the northwest part of Stockbridge on land of Mr. Buck; whose thickness was about

two and a half feet, and probable extent, very great. Also a second bed in the same town, only four miles from the court-house in Lenox. Also a third bed in the northeast part of Lee, at the Mills of Sedgwick and Co., the thickness of which, in some places, is about ten feet; though its extent is but a few acres. Also, several beds in West Stockbridge in various parts of the town. The limited time which I gave to these researches did not allow me to make but slight examinations in other towns. But I have little doubt that similar beds of marl will be found in various other places in the County; especially in Sheffield, Great Barrington, Egremont, Alford, Richmond, Lanesborough, New Ashford, and perhaps in Williamstown, Adams, Cheshire, Dalton, and New Marlborough. I am confirmed in this opinion from the fact that since I visited the County several other beds have been discovered.

A second bed has been found in Pittsfield, about a mile south-east of the village. Also a bed in Stockbridge, a little northeast of the village on the road to Lenox. For specimens from both which places, I am indebted to Professor Dewey. A third bed has been found covering several acres in the north-west part of Lee, near a pond, on land of Messrs. Lemuel and Cornelius Bassett. The thickness of the marl, which commences about a foot below the surface, is in some places from four to seven feet, and in others, from ten to twelve feet; and from 200 to 300 loads have been taken from it by the Messrs. Bassett. Specimens from all the beds that have been described will be found in the collection accompanying this Report. (See Nos. 148, 149, 150, 151, 152, 153, 172, 173, 174, 175.) I am informed also, that a small bed exists in Tyringham, and another in Sheffield, and two at least occur in Great Barrington.

The purest of these marls when dry, are almost as white as chalk, and much lighter than common soil, as may be seen from the specific gravities of a part of them in the table of their analysis below. When wet they are of a light gray color, especially if they contain much organic and earthy matter: indeed the degree of their whiteness is no bad index of the quantity of lime that they contain. When wet they are quite plastic and adhesive: when dry, they fall into a fine powder. Hence they are in a most favorable state for being spread upon land. They are found almost exclusively in swampy ground, generally in quite wet swamps, and are always covered by a stratum, often several feet thick, of black vegetable matter approaching to peat. Hence, as these swamps are rarely excavated, the marl is not apt to be discovered; or if found, it is supposed to be nothing more than white clay and sand, which, indeed, it does very much resemble. In order to ascertain the presence of marl in a swamp, I prepared an iron rod, several feet long, near the end of which was a grove, in fact it formed a sort of auger. When pressed into the ground and withdrawn, it would always retain in the groove

some of the matter from the bottom of the hole, and in this way, in a few minutes, not only the existence of marl might be ascertained, but the thickness of the bed. Yet after all, since the swamps where it occurs are usually very wet, and easily penetrated, a rough pole is better for discovering marl and its thickness, than the iron borer which I have described. For some of it will adhere to a pole plunged into it, even though that pole must be drawn through several feet of vegetable mud above it. And if the pole be plunged to the bottom of the bed, the distance along the pole covered with marl, will show the thickness of the bed; except that the lower extremity of the pole will show beneath the layer of marl the clay or sand as far as they were penetrated: and this extent must be subtracted from the whole length covered with marl. I have been thus particular in describing the method of searching for marls, in the confidence that if gentlemen residing in the towns above mentioned will adopt it, many new beds will be brought to light.

There is a substance in the central and eastern parts of the State, in exactly the same situation as the marl of Berkshire, which resembles it also very precisely in external characters, and is also like marl very light; and yet it is not marl. It does not contain carbonate of lime, but is composed chiefly of silica. Specimens of it will be found in the collection from several places. (See No. 157, which is from Spencer; No. 169, from Barre, and No. 170, from Andover.) It is easy, notwithstanding its general resemblance, to distinguish it from marl by a few drops of vinegar, oil of vitriol, aqua fortis, or any other acid. If a substance be marl, the acid will produce in it small bubbles occasioned by the escape of gas—if not marl, no effervescence will be produced. And this is a universal test, which is almost infallible, for distinguishing marl in all circumstances.

One other circumstance respecting the Berkshire marl, which will aid in distinguishing it. It abounds every where with small fresh water shells, such as now occur in the ponds of that region, and therefore it is unquestionably true fresh water marl, usually called shell marl. The epidermis of the shell is usually gone. Such shells are rarely found in much quantity where lime does not exist, although I have seen them in mud that did not effervesce. But their presence should lead us to search carefully for calcareous matter: for how can these animals form their shells without lime?

The Berkshire marls, above described, appear to me to be some of the richest and best that ever occur. Marls are usually valued only for the calcareous matter which they contain. But by adopting Dr. Dana's method of analysis, we find that they also contain no small quantity of soluble and insoluble geine, derived from the vegetable matter that covers them. This must make them still more valuable when applied to the soil. They contain likewise a small portion of phosphate of lime, increasing their value still

more: while the silicates in them, the only part that is of no value, are in most cases extremely small. The following are the results of the analysis of the specimens in the Government collection.

I have added the analysis of a specimen of similar marl from Farmington in Connecticut, for which I am indebted to Professor Silliman. For the geological character of Farmington and the surrounding region is very much like that of Springfield and West Springfield; and therefore I cannot but hope that some of the swamps in the latter places may contain it. The bed in Farmington is said to be extensive.

Marl of this description is usually supposed to result wholly from the decomposition of minute fresh water shells: But since it is not unusual for water in limestone to contain a small quantity of carbonate of lime in solution, by means of free carbonic acid, it seems to me that the deposition of this carbonate of lime in a pulverulent state, in consequence of the escape of the acid, is the probable origin of a large part of the marl.

| No. | LOCALITY. | Soluble Geine. | Insoluble Geine. | Phosphate of Lime. | Carbonate of Lime. | Carbonate of Magnesia. | Silicates. | Water of Absorption. | Specific Gravity. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|
| 148 | Stockbridge, (Mr. Buck's Farm,) | 4.3 | 4.6 | 0.7 | 73.4 | 0.15 | 13.5 | 3.3 | 1.82 | 2 1-2 feet thick. |
| 151 | do northeast of the village, | 5.0 | 8.9 | 0.6 | 46.0 | trace. | 36.6 | 2.9 | | |
| 203 | do do - - - - | 0.6 | 3.8 | 0.8 | 31.8 | | 59.8 | 1.7 | | 1.5 Sulphate of Lime: Specimen from another part of the bed. |
| 149 | Pittsfield, east of the village, | 3.1 | 3.5 | 0.7 | 86.4 | 0.46 | 3.1 | 3.0 | 1.82 | 4 feet thick at least. |
| 152 | do S. W of village (Mr. Strong's lot,) - - - - | 3.1 | 3.2 | 0.4 | 64.8 | trace. | 25.2 | 1.9 | | |
| 150 | West Stockbridge, Mr. Reed's land,) - - - - | 1.7 | 5.0 | 0.5 | 74.8 | 0.53 | 14.7 | 2.8 | 1.61 | |
| 153 | Lee, Sedgwick & Co's mills,) | 1.2 | 2.1 | 1.0 | 93.2 | no trial | 0.9 | 1.6 | 1.89 | Exposed to the action of running water. |
| 172 | do (L. Basset's bed, near the surface,) - - - - | 1.8 | 2.2 | 1.4 | 93.0 | do | 2.2 | 0.4 | | 9 to 12 feet thick. |
| 173 | do do 10 feet below the surface, - - - - | 1.6 | 2.8 | 1.0 | 88.8 | do | 4.4 | 1.4 | 1.75 | |
| 174 | do (C. Bassett's bed,) - - | 2.6 | 3.4 | 1.2 | 86.2 | do | 5.0 | 1.6 | | Nos. 172, 173 and 174 are from the same bed. |
| 175 | do (Sedgwick's mills,) - - | 0.8 | 4.4 | 1.0 | 83.6 | do | 9.2 | 1.0 | | Not Exposed to the action of running water. |
| 204 | Farmington, Ct. - - - - | 3.0 | 9.5 | 0.4 | 64.4 | do | 17.8 | 2.9 | | 2.0 Sulphate of lime. No trial for the sulphate in the other specimens. |

The amount of calcareous matter in these marls is unusually large, with the exception of one of the specimens from Pittsfield, and another from the east part of Stockbridge. And these specimens were not taken directly from the beds, but as they had been thrown out in making excavations; and the marl was obviously mixed with loam and sand; so that the quantity of carbonate of lime by the analysis is doubtless too small.

Again, most marls are only in part pulverulent, or easily crumbled down, and they require a long time after being mixed with the soil, before they will exert a favorable action upon it. But these are all in a state best adapted for immediate use; and when we add to these considerations those already made concerning the other ingredients of these marls, I cannot but feel that Berkshire possesses in them a very great treasure. I doubt not but an inexhaustable supply may be found there, not only for the county but for exportation. And since the most numerous beds yet discovered occur very near the point (West Stockbridge) where two great rail roads are soon to intersect, I cannot doubt that this marl will be among the articles of export at least a considerable distance. The marls of New Jersey and Virginia, it is well known, are already beginning to be transported a great distance. And if any marls are rich enough to be thus conveyed by land or water, surely those of Berkshire must be of the number. It will doubtless require a long time to satisfy many of our farmers of the value of marl: and especially as we may expect many failures from applying this marl in improper quantity, or in the neglect of collateral circumstances essential to success. But unless a vast amount of experience in the use of marl in Europe and in this country is to be set aside as a ground of judgment, these marls must sooner or later work an important improvement in a portion of the agriculture of this State.

There is an important fact derived from the analysis of soils that have been given, relative to the character of those in Berkshire county. It had formerly been supposed, that the soils of that county contain so much lime that marls would be of no service there. But it appears that they contain scarcely any more of this substance, either in the form of carbonate, sulphate, or phosphate, than the other soils of the state. At least, the specimens analyzed do not; and these were taken at random from fields underlaid by limestone; so that probably they show about the average quantity of lime in the soils of the county; though I doubt not that soils may be found there containing more of this substance. I think this may be a safe rule to follow by the farmers of that county. If a soil effervesces with vinegar, or other acids, they may infer that marl will be of little service. If it do not effervesce, they may safely apply marl. And judged of by this rule, I doubt not that four out of five of the Berkshire soils will be found to need it. It ought to be expected, however, that this rule will sometimes fail; because a soil may contain lime in some other form than the carbonates, so that for several years the marl may do no good.

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3 2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 32 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.6 | 0.6 | 93.8 | | | 2·58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1,4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5,4 | 5.3 | 1.0 | | 0.7 | 87 6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0 5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2 29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1 5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3 8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1,7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0 9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2,54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0 6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0 6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4 6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5 7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0 7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, - - - - | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, - - - - | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, - - - - | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, - - - - | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, - - - - | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, - - - - | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2 40 |
| 108 | do Gloucester, - - - - | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, - - - - | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, - - - - | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, - - - - | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, - - - - | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, - - - - | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, - - - | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, - - - - | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, - - - - | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, - - - - | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, - - - - | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. - - | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, - - - - | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, - - - - | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, - - - - | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, - - - | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, - - - - | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, - - - - | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 127 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies,* wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen,* act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 | phos. lime, | 3.3 | phos. iron. |
| " | Birch | 7.3 | " | 1.25 | " |
| " | Oak wood | 1.8 | " | | |
| " | Alder coal | 3.45 | " | 9.00 | " |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Candolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung,* as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. *(Third Report on the Geology of Maine, p. 150.)*

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxŭriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c.*" *London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, " it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon ! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid ! Plants he conceives are nourished almost entirely by carbonic acid; and he says that " possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids ;—the crenic, the apocrenic, and ulmic ; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol.* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has " satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist " with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence ?* Why may it not be a compound of these, and perhaps other acids, and other ingredients ? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance ? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 oz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates*, because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

### *Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

### *Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | |
|---|---|---|---|
| Ashes of wheat, | 48 Silica, | 37 Lime. | 15 Alumina. |
| " of oats, | 68 " | 26 " | 6 " |
| " of barley, | 69 " | 16 " | 15 " |
| " of rye, | 63 " | 21 " | 16 " |
| " of potatoes, | 4 " | 66 " | 30 " |
| " of red clover, | 37 " | 33 " | 30 " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an alumnious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

### *Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

### *Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | | |
|---|---|---|---|---|
| " | 80 | Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " | 186 | do Sandisfield, | 2.80 | " |
| " | 113 | Sienite Soil, Wrentham, | 0.40 | " |
| " | 125 | Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

### *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

velopment of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell, to whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin.* More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they call it *Humin;* but Berzelius adopts the name of *Geine.* When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalies upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates,* most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity, and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analyzing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturalist. Those of Dr. Dana appear to me to be far more important; although essentially coinciding with those of European chemists. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and elegant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable It can affect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine: but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali;* and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest: magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates*, always more soluble than neutral salts. Soluble geine, therefore, includes the watery solution—the solid extract caused by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluble geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those alrea-

dy quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of the soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is composed wholly or chiefly, of one earth; or any soil, with excess of salt, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification:—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into "*silicates*;" by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphates have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphate of lime, than on its animal portion. Though the same plants growing in different soils are

found to yield variable quantities of the *salts* and earthy compounds, yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granitic rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the silicates are decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is chiefly *silicates*, using the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, or too clayey, may be modified by mixture; but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analyzing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

### *Rules of Analysis.*

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus, or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear: wash the grounds with 4 ounces boiling water: throw all on a double weighed filter, previously dried at the same temperature as was the soil (1); wash till colorless water returns. Mix all these liquors. It is a

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, - - - - | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, - - - - | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, - - - - | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, - - - - | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, - - - - | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, - - - - | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, - - - | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, - - - - | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) - | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, - - - - | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, - - - - | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, - - - | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, - - - - | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, - - - | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, - - | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, - - | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, - - | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, - - | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, - - | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, - - - | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, - - - | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, - | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, - - | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, - - - | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* - - - | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, - - - | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, - - - | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. - - - | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, - - | 3.2 | 0.5 | 3.2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, - - - | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, - - | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, - - - | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, - - - | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, - - - | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, - - - | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, - - - | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, - - - | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, - - | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 32 | 2.48 |
| 33 | do Quincy, - - - | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, - - | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, - - - | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, - - - | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, - - - | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, - - - | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, - | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, - | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, - - - | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, - - - | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, - - - | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, - - | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, - - | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, - - | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, - - | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, - - - | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.5 | 0.6 | 93.8 | | | 2.58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1.4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5.4 | 5.3 | 1.0 | | 0.7 | 87.6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0.5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2.29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1.5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3.8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1.7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0.9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2.54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0.6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0.6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4.6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5.7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0.7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2.40 |
| 108 | do Gloucester, | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6.5 | 130 | 2.24 |
| 110 | do Danvers, | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 1?7 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

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ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies,* wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen,* act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | |
|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 phos. lime, | | 3.3 phos. iron. | |
| " | Birch | 7.3 | " | 1.25 | " |
| " | Oak wood | 1.8 | " | | |
| " | Alder coal | 3.45 | " | 9.00 | " |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Candolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung,* as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

*Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. (*Third Report on the Geology of Maine, p.* 150.)

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxüriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c.*" *London,* 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schubler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 oz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates*, because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

### *Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

### *Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

## *Experiments on the Retaining Power of Soils.*

| No. | Loss of 200 grs. in 3 1-2 hours June. 25 | Gain at night | Loss in 2 1-2 hours June 26. | Additional loss in 4 hours July 1. |
|---|---|---|---|---|
| 1 | 100 | 5 | 100 | 6 |
| 2 | 96 | 7 | 98 | 8 |
| 3 | 93 | 6 | 99 | 7 |
| 4 | 100 | 7 | 105 | 3 |
| 5 | 102 | 8 | 103 | 6 |
| 6 | 100 | 5 | 103 | 4 |
| 7 | 99 | 8 | 101 | 2 |
| 8 | 103 | 8 | 105 | 4 |
| 9 | 99 | 9 | 101 | 8 |
| 10 | 102 | 9 | 105 | 5 |
| 11 | 100 | 7 | 105 | 3 |
| 12 | 101 | 7 | 97 | 10 |
| 13 | 100 | 7 | 101 | 8 |
| 14 | 102 | 8 | 102 | 8 |
| 15 | 101 | 5 | 103 | |
| 16 | 101 | 7 | 104 | |
| 17 | 101 | 7 | 104 | |
| 18 | 100 | 5 | 108 | |
| 19 | 95 | 6 | 107 | |
| 20 | 99 | 4 | 102 | |
| 21 | 101 | 6 | 109 | |
| 22 | 100 | 4 | 104 | |
| 23 | 88 | 5 | 109 | |
| 24 | 101 | 6 | 104 | |
| 25 | 101 | 4 | 108 | |
| 26 | 103 | | | |
| 27 | 102 | 9 | 101 | 8 |
| 28 | 101 | 7 | 104 | 5 |
| 29 | 100 | 7 | 97 | 12 |
| 30 | 102 | 10 | 105 | 5 |
| 31 | 101 | 10 | 108 | 4 |
| 32 | 98 | 11 | 108 | 5 |
| 33 | 102 | 12 | 103 | 9 |
| 34 | 100 | 11 | 103 | 9 |
| 35 | 82 | 14 | 102 | 14 |
| 36 | 101 | 9 | 104 | 6 |
| 37 | 97 | 12 | 108 | 4 |
| 38 | 101 | 12 | 107 | 5 |
| 39 | 101 | 11 | 106 | 7 |
| 40 | 101 | 13 | 102 | 13 |
| 41 | 92 | 13 | 105 | |
| 42 | 101 | | 104 | |
| 43 | 106 | | 112 | |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional loss in 4 hours. |
|---|---|---|---|---|
| 44 | 105 | 17 (?) | 112 | |
| 45 | 106 | 14 | 111 | |
| 46 | 103 | 13 | 100 | |
| 47 | 100 | 9 | 106 | |
| 48 | 102 | 9 | 100 | |
| 49 | 103 | 11 | 111 | |
| 50 | 102 | 8 | 105 | |
| 51 | 102 | 11 | 105 | 8 |
| 52 | 102 | 13 | 104 | 9 |
| 53 | 102 | 12 | 103 | 10 |
| 54 | 103 | 13 | 103 | 11 |
| 55 | 103 | 10 | 101 | 12 |
| 56 | 101 | 7 | 100 | 9 |
| 57 | 102 | 9 | 106 | |
| 58 | 104 | 15 | 105 | |
| 59 | 100 | 12 | 103 | |
| 60 | 102 | 8 | 108 | |
| 61 | 102 | 9 | 104 | |
| 62 | 101 | 8 | 100 | 4 |
| 63 | 103 | 14 | 108 | 5 |
| 64 | 104 | | 108 | 4 |
| 65 | 105 | 17 (?) | 105 | 9 |
| 66 | 114 | 13 | 107 | 6 |
| 67 | 104 | 12 | 108 | 4 |
| 68 | 96 | 5 | 110 | |
| 69 | 107 | 15 | 109 | 1 |
| 70 | 106 | 12 | 106 | 2 |
| 71 | 104 | 11 | 106 | 3 |
| 72 | 104 | 9 | 107 | 0 |
| 73 | 109 | 13 | 104 | 1 |
| 74 | 104 | 7 | 91 | 14 |
| 75 | 99 | 7 | 93 | 12 |
| 76 | 101 | 9 | 97 | 10 |
| 77 | 101 | 10 | 101 | 5 |
| 78 | 102 | 9 | 105 | 1 |
| 79 | 100 | 9 | 102 | 5 |
| 80 | 102 | 12 | 111 | 1 |
| 81 | 101 | 13 | 111 | 10 |
| 82 | 101 | 5 | 95 | |
| 83 | 104 | 9 | 107 | |
| 84 | 106 | 10 | 104 | |
| 85 | 106 | 8 | 104 | |
| 86 | 103 | 6 | 102 | |
| 87 | 109 | 13 | 104 | |
| 88 | | 11 | 105 | |
| 89 | | 14 | 106 | 5 |
| 90 | | 12 | 108 | 1 |

Bergman found one of the most fertile soils in Sweden to contain

| | |
|---|---|
| Coarse Silica (sand,) | 30 |
| Silica, | 26 |
| Alumina, | 14 |
| Carbonate of Lime, | 30 |

Giobert found the following to be the composition of one of the most fertile soils in the neighborhood of Turin.

| | |
|---|---|
| Silica, | 77 to 79 |
| Alumina, | 9 to 14 |
| Carbonate of Lime, | 5 to 12 |

A very fertile soil in France gave, according to the analysis of Chaptal,

| | |
|---|---|
| Siliceous Gravel, | 32 |
| Calcareous Gravel, | 11 |
| Silica, | 10 |
| Alumina, | 21 |
| Carbonate of Lime, | 19 |
| Organic Matter, | 7 |

The most fertile mixture obtained by Tillet, in numerous experiments made at Paris, contained the following ingredients.

| | |
|---|---|
| Coarse Silica (Sand,) | 25.0 |
| Silica, | 21.0 |
| Alumina, | 16.5 |
| Carbonate of Lime. | 37.5 |

*(Chaptal's Chemistry applied to Agriculture, p. 25. first Boston Edition.)*

*Inferences.*

Though the analyses quoted above are referred to different standards, yet it is easy to see that the earthy ingredients are exceedingly various, if we look only to the most fertile soils. In one, that from Somerset in England, siliceous sand and carbonate of lime constitute 98 per cent. of the soil; while alumina is less than one per cent. In most of those from Massachusetts, there is no carbonate of lime, and only one or two per cent. of lime in any combination. The prairie soils of the Western States, confessedly among the most fertile on the globe, appear to contain a larger proportion of silica and a less proportion of alumina, than almost any variety of soil from Massachusetts. Upon the whole, the facts stated above, taken in connection with settled principles in Agricultural Chemistry, will warrant the following inferences.

1. A soil composed wholly or chiefly of one kind of earth will not produce any healthy vegetation. If nineteen twentieths be silica, or alumina, lime, or magnesia, it is said that it will be barren. On this account

the numerous sand hills or dunes in the southeastern part of Massachusetts, are almost entirely barren; and it appears from the first table of analysis which I have given, that these sands contain less than one twentieth of finely divided matter. In England however, a writer on this subject (*Rees Cyclopedia, Article, Soil,*) say sthat he has seen a tolerable crop of turnips on a soil containing eleven out of twelve parts of sand. Any one may also see in Plymouth and Barnstable counties in the summer, very good crops of wheat on land similar to that analysed from Wareham, which contains 85 per cent. of silica.

2. Though plants may be made to grow in soils composed of only two sorts of earths, yet in order to render them very fertile, it is necessary that they should contain at least silica, alumina, and lime; and probably also iron and magnesia are important. That these ingredients are wanted by most plants is evident from their analysis: although we are not perhaps warranted in saying that they are all indispensable to a tolerably healthy development of the plant. 100 parts of the ashes of the following plants were found to contain as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ashes of wheat, | 48 | Silica, | 37 | Lime. | 15 | Alumina. |
| " of oats, | 68 | " | 26 | " | 6 | " |
| " of barley, | 69 | " | 16 | " | 15 | " |
| " of rye, | 63 | " | 21 | " | 16 | " |
| " of potatoes, | 4 | " | 66 | " | 30 | " |
| " of red clover, | 37 | " | 33 | " | 30 | " |

Most plants also contain several salts soluble in water: also earthy phosphates, and carbonates and metallic oxides: as may be seen by consulting Chaptal's Chemistry applied to Agriculture, p. 176. Now if those ingredients be not furnished by the soil, from whence can the plants obtain them?

3. Only a small quantity of earthy ingredients is required for plants; and hence the proportions in which they exist in the soils may vary exceedingly without affecting their fertility, so far as the food of the plant is concerned.

4. The degree of comminution or fineness in a soil, is of far more importance in its bearing upon fertility, than its chemical composition, so far as the earthy ingredients are concerned. The power of a soil to absorb and retain moisture, as well as the power of the rootlets of plants, to take up nourishment from the soil, depend in a great measure upon its fineness. If the particles be too coarse to accomplish these objects, it can be of little consequence whether those particles are pure silica, or alumina, or lime, or iron, or a mixture of the whole. And if they be fine enough, I do not see why one kind may not answer nearly as well as another, provided enough of them all be present to enter into the composition of the plants: though doubtless al-

umina of the same fineness would be of a closer texture and absorb more moisture, than the others. The soils of New England are usually regarded as too siliceous: and yet, from the preceding table it seems they are less so than the rich prairie soils of the western states. But these western soils are reduced almost to an impalpable powder, more fine than even any of the alluvium of Massachusetts that I have seen: and I apprehend that this is a principal cause of their fertility.

5. Hence we infer, that in some instances, one earthy ingredient may be substituted for another. In a letter from A. A. Hayes Esq. of Roxbury, whose opinion on this subject cannot but be highly appreciated, he says, "The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an alumnious soil to a certain extent; and that the existence of a due proportion of finely divided matter is of more consequence than is its composition." In this view of the subject, the mechanical part of Davy's rules for the analysis of soils, becomes of more importance than the chemical part. And the mechanical part, that is, the determination of the quantity of finely divided matter, can be performed by every farmer of tolerable ingenuity with a very few articles of apparatus.

6. It appears that to spend much time in an accurate chemical determination of the earthy constituents of soils, is of little importance. If there was any one definite compound of the earths which would always give the maximum of fertility, such analyses would be important: but I have shown, if I mistake not, that great diversity in this respect is consistent with the highest amount of fertility. Or if it should prove true, as I confidently think it will not, that there is a particular proportion of earthy ingredients most favorable to fertility, as Tillet undertook to show in respect to Paris, I apprehend that the same proportion will not produce the maximum of fertility in countries where the temperature and the amount of rain are different.

There is one respect, however, in which this kind of analysis may be of service in a region like New England, where lime exists in the soil in such small proportion; and that is, to determine whether it exists at all. There is another method, however, of ascertaining the presence of the most important salts of lime in a soil, which I shall explain shortly, and which is more easy than analysis in the dry way by alkali.

The fact is, every farmer is acquainted with the difference between sandy, clayey, and loamy soils; and it is doubtful whether the most delicate analysis will afford him much assistance of much practical value in respect to these distinctions.

I could easily have analyzed all the soils which I have collected in the

manner that has been described. But for the reasons above given, and because a new mode of analysis of greater value was unexpectedly brought to my notice, I have judged it inexpedient to proceed. I wish however to say, that in thus giving my opinion of the entire inadequacy of most of the steps in Davy's rules for the analysis of soils, I do not mean to intimate that it is owing to any want of skill in that distinguished chemist: but simply because he attempted an impossibility, viz. to frame popular rules for such analyses as can be performed only by the experienced chemist and with the best apparatus and ingredients.

7. Finally, if these positions be correct, then it follows that almost every variety of soil may by cultivation be rendered fertile. If we can only be certain that silica, alumina, and lime, are present, we need not fear, but by those modes of cultivation which every enlightened farmer knows how to employ, it may be made very productive. In nearly all the soils in Massachusetts, for instance, the only question will be respecting the presence of lime; since he may be sure the other constituents are present. It is not necessary, therefore, for our young men to go to distant regions in search of fertile soils. Patient industry will ensure them such soils within their own borders: and the same may be said of nearly every country: a fact which strikingly exhibits the Divine Beneficence.

### *Analysis for determining the salts and organic matter of Soils.*

With the exception of carbonate of lime, which I have regarded as one of the earthy ingredients of soils, although it is properly a salt, the amount of organic matter in a soil cannot be greatly diminished, nor that of salts greatly increased, without rendering it sterile. And yet, the existence of both salts and organic matter seems essential to successful cultivation. It hence becomes a matter of no little importance, to ascertain the existence and amount of these substances in soils. This it is true, can be done by the modes of analysis already described: But in respect to some important salts, especially the phosphates, it is well known that their detection by the ordinary modes of analysis is very difficult. And in respect to the organic matter, the method hitherto proposed by Davy, Chaptal, and others, simply ascertains its amount by burning it off. Now it is well known that a field may abound in organic matter, as for instance a peaty soil, and yet be entirely barren. Another field may contain but little organic matter, and yet be very productive; though soon exhausted. The same quantity of manure on one field, will render it productive much longer than another field. On one field it is rapidly dissipated: on another, it is fixed, or so combined as to be permanent. Hence it is of greater importance to determine what

is the condition of organic matter in a soil, than its amount. It seems to be well ascertained, that in order to its being taken up by the rootlets of plants, it must be in a state of solution; and in order to prevent its being dissipated, it must be chemically combined with some of the earthy ingredients of the soil. But these matters have hitherto been scarcely touched in the rules given for analysis. This desideratum, however, has in my opinion been in a good measure supplied by a chemical friend, and will be described in the sequel.

### *Examination for Carbonate of Lime.*

Many of the analyses of European soils, represent them as containing a rather large per centage of carbonate of lime: and hence it was natural to expect a similar constitution in the soils of this country. But the result is different from the anticipation. In order to determine this point, I adopted the following method. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was coverd with water to a considerble depth. The soil was then stirred until the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived.

I am confident that if in 100 grains of the soil, (the quantity usually employed) the fiftieth part of a grain had existed, it might in this manner have been detected. The result disclosed the remarkable fact, that out of 145 soils examined from all parts of the state, and some of them underlaid by limestone, only 14 exhibited any effervescence; and even these, when analyzed, yielded but a small per centage of carbonate of lime: viz.

| | | | | |
|---|---|---|---|---|
| No. 176 | Alluvial Soil, Westfield, | | 6.2 | per cent. |
| " 180 | Sandy Soil, Truro, | | 21.3 | " |
| " 35 | Graywacke Soil, Watertown, | | 1.30 | " |
| " 51 | Limestone Soil, Sheffield, | | 0.80 | " |
| " 52 | do | West Stockbridge, | 3.20 | " |
| " 192 | do | Saddle Mountain Adams, | 1.50 | " |
| " 189 | do | Richmond, | 0.80 | " |
| " 183 | Argillaceous Slate Soil, Boston Corner, | | 2.98 | " |
| " 196 | Talcose Slate Soil, Mount Washington, | | 2.77 | " |
| " 78 | Gneiss Soil, Westminster, | | 3.00 | " |

| | | | |
|---|---|---|---|
| " 80 | Gneiss Soil Fitchburg, | 2.10 | per cent. |
| " 186 | do Sandisfield, | 2.80 | " |
| " 113 | Sienite Soil, Wrentham, | 0.40 | " |
| " 125 | Greenstone Soil, Deerfield, | 2.00 | " |

Even in several of the above instances I am convinced that the calcareous matter was not natural to the soil. Thus, I afterwards learnt that the field in Westfield, (about a mile west of the village,) from which the above specimen was taken, had been highly manured; and having collected another specimen in an adjoining field, I could detect no carbonate in it. Nos. 31, 78, 80, and 125 also, contrary to my usual custom, were obtained in small patches of cultivated ground near villages; and most probably these had been highly manured if not with lime yet with substances that might produce a carbonate of some sort. And No. 180 was full of fragments of sea shells. Setting aside these specimens, we find that only one in 10 of our soils contains any carbonate of lime; and if we leave out of the account, the soils from the limestone region of Berkshire, we may consider nearly every other soil in the state as destitute of that substance. Even in Berkshire, it is rare to meet with soils that effervesce; and I have found none there, that contained but a very small proportion of the carbonate of lime. From the able work of Edmund Ruffin Esq. of Virginia, on calcareous manures, it appears that the same is true of the soils of that state: and also of some of the western states; even where limestone is the prevailing rock. The analyses of western soils, also, which I have given, show but a small proportion of this ingredient. Upon the whole, I think we may fairly infer that the soils in general in this country are less charged with carbonate of lime than those of Europe. In the primitive parts of our country, such as New England, this is easily explained, from the great dearth of limestone. In other parts, perhaps the fact may be explained by the powerful effects of diluvial action, and the more compact nature of our limestone in our vast secondary deposites, whereby they are less liable to disintegration, than many of those in Europe. Or not improbably, the great amount of vegetation, that has for thousands of years spread over our country, while it has added to the organic matter of the soil, may have used up much of the carbonate of lime: For that the growth of vegetables will gradually consume the calcareous matter of the soil, seems now pretty well established.

## *New Method of analyzing Soils.*

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the de-

velopment of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell, to whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin.* More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they call it *Humin;* but Berzelius adopts the name of *Geine.* When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalies upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates,* most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity, and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analyzing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturalist. Those of Dr. Dana appear to me to be far more important; although essentially coinciding with those of European chemists. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and elegant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable It can affect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine: but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali;* and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest: magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates*, always more soluble than neutral salts. Soluble geine, therefore, includes the watery solution—the solid extract caused by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluble geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those alrea-

dy quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of the soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is composed wholly or chiefly, of one earth; or any soil, with excess of salt, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification:—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into "*silicates*;" by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphates have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphate of lime, than on its animal portion. Though the same plants growing in different soils are

found to yield variable quantities of the *salts* and earthy compounds, yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granitic rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the silicates are decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is chiefly *silicates*, using the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, or too clayey, may be modified by mixture; but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analyzing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

## *Rules of Analysis.*

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus, or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear: wash the grounds with 4 ounces boiling water: throw all on a double weighed filter, previously dried at the same temperature as was the soil (1); wash till colorless water returns. Mix all these liquors. It is a

brown colored solution of all the soluble geine. All sulphates have been converted into carbonates, and with any phosphates, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh—the loss is *soluble geine.*"

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly subside, and if lime-water enough has been added, the natant liquor will be colorless. Collect the geate of lime on a filter: wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh. Deduct the weight from the soluble geine, (rule 1.) the remainder is the amount of alumina, oxide of iron, magnesia, sulphuric and phosphoric acids contained in the alkaline solution."

4. "Replace on a funnel the filter (2) and its earthy contents: wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphate of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present: but hydrates exist in too small quantities in soils to affect the result. The actual weight of the residuary mass shows the amount of *Silicates* in the soil.

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before: the loss of weight is due to the *sulphate of lime:* even the sulphate of iron may be so considered: for the ultimate result in cultivation is to convert this into sulphate of lime."

"Treat the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."

As soon as made acquainted with this mode of analysis, it appeared to me so much more important and accurate than any other with which I was conver-

sant, that I felt determined, if possible, to apply it to the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected, viz. 146: and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alluvium—Deerfield, | 3.5 | 1·2 | 2.0 | | 0.9 | 92.4 | 3.3 | 65 | 2·44 |
| 2 | do Northampton, | 2.8 | 4.2 | 2.4 | | 1.0 | 89.6 | 2.0 | 40 | 2 45 |
| 3 | do Deerfield, | 2.3 | 1.1 | 1.6 | | 0.9 | 94.1 | 2.1 | 42 | 2.58 |
| 4 | do Northampton, | 1.2 | 2.4 | 0.9 | | 1.1 | 94.4 | 1.2 | 25 | 2.68 |
| 5 | do Northfield, | 2.8 | 2.8 | 1.5 | | 0.6 | 92.3 | 2.9 | 58 | 2.55 |
| 6 | do Northampton, | 2.4 | 0.8 | 2.8 | | 0.8 | 93.2 | 1.4 | 28 | 2.55 |
| 7 | do W. Springfield, | 3.2 | 1·2 | 1.3 | | 0.7 | 93.6 | 3.0 | 60 | 2.46 |
| 176 | Alluvium—Westfield, | 2.4 | 2.7 | 2.6 | 6.2 | 1.0 | 85.1 | | | 2.38 |
| 177 | do do (an adjoining field,) | 1.5 | 1.2 | 0.9 | | 0.3 | 96.1 | | | |
| 8 | do Stockbridge, | 3.3 | 0.8 | 2.9 | | 0.5 | 92.5 | 1.9 | 38 | 2.55 |
| 9 | do Hadley, | 2.5 | 2.3 | 2.7 | | 1.0 | 91.5 | 5.0 | 100 | 2.46 |
| 10 | do Sheffield, | 1.3 | 5.2 | 1.7 | | 0.5 | 91.3 | 3.5 | 70 | 2.53 |
| 11 | do Deerfield, | 2.5 | 2.4 | 0.8 | | 0.8 | 93.5 | 2.0 | 40 | 2.58 |
| 12 | do W. Springfield, | 1.5 | 1.5 | 1.0 | | 0.5 | 95.5 | 1.5 | 30 | 2.65 |
| 13 | Diluvial Argillaceous—Springfield, | 4.8 | 5.8 | 2.4 | | 1.2 | 85.8 | 6.3 | 126 | 2.31 |
| 14 | do do Northampton, | 4.8 | 4.6 | 1.6 | | 0.8 | 88.2 | 6.1 | 122 | 2.37 |
| 15 | do do Plymouth, | 2.9 | 4.9 | 1.8 | | 0.9 | 89.5 | 4.9 | 98 | 2.34 |
| 16 | do do Barnstable, | 4.4 | 5.9 | 0.9 | | 0.6 | 88.2 | 4.9 | 98 | 2.39 |
| 17 | do do Sandwich, | 2.8 | 4.9 | 3.0 | | 1.1 | 88.2 | 4.2 | 84 | 2.37 |
| 18 | do Sandy—Wareham, | 0.5 | 0.0 | 0.4 | | 0.4 | 98.7 | 0.5 | 10 | 2.37 |
| 19 | do do Springfield, | 3.2 | 0.0 | 1.6 | | 0.6 | 94.6 | 1.7 | 34 | 2 60 |
| 168 | do do uncultivated, Northampton, | 3.6 | 4.4 | 0.5 | | 0.5 | 91.0 | | | |
| 179 | do Loamy—Amherst, | 3.5 | 2.3 | 2.5 | | 0.9 | 90.8 | | | 2.37 |
| 178 | do Sandy—Sheffield, | 0.0 | 0.8 | 03.2 | | 0.08 | 98.8 | | | 2.66 |
| 180 | do do Truro,* | 3.7 | 1.6 | | 21.3 | 0.35 | 73.1 | 1.7 | 34 | |
| 20 | do do Barnstable, | 0.0 | 0.0 | 0.1 | | 0.3 | 99.6 | 0.8 | 16 | 2.72 |
| 21 | do do Gloucester, | | | | | | 100. | 0.7 | 14 | 2.71 |
| 22 | Sandstone, (Red,)—Deerfield. | 0.3 | 2.6 | 0.8 | | 0.7 | 95.6 | 3.4 | 68 | 2.53 |
| 23 | Sandstone, (Red,)—Longmeadow, | 3.2 | 0.5 | 3 2 | | 0.6 | 92.5 | 3.2 | 64 | 2.43 |
| 24 | do do Wilbraham, | 6.1 | 2.0 | 1.0 | | 0.8 | 90.1 | 2.5 | 50 | 2.60 |
| 25 | do do W. Springfield, | 4.1 | 3.8 | 4.3 | | 0.7 | 88.1 | 2.7 | 54 | 2.46 |
| 26 | do (Gray,)—Granby, | 2.7 | 1.8 | 0.6 | | 0.8 | 94.1 | 3.0 | 60 | 2.51 |
| 27 | Graywacke Soil—Dorchester, | 7.6 | 2.1 | 1.8 | | 1.0 | 87.5 | 4.5 | 90 | 2.37 |
| 28 | do Roxbury, | 4.4 | 3.8 | 2.3 | | 1.4 | 88.1 | 3.9 | 78 | 2.43 |
| 29 | do Brookline, | 6.0 | 5.3 | 3.1 | | 1.4 | 84.2 | 5.8 | 116 | 2.34 |
| 30 | do Walpole, | 2.6 | 5.5 | 1.9 | | 0.8 | 89.2 | 3.1 | 62 | 2.31 |
| 31 | do Dighton, | 2.1 | 3.4 | 1.9 | | 0.5 | 92.1 | 1.5 | 30 | 2.34 |
| 32 | do Middleborough, | 1.2 | 3·7 | 2.1 | | 0.9 | 92.1 | 1.6 | 82 | 2.48 |
| 33 | do Quincy, | 2.1 | 5.0 | 2.4 | | 1.5 | 90.0 | 3.5 | 70 | 2.44 |
| 34 | do W. Bridgewater, | 3.4 | 2.3 | 1.2 | | 0.6 | 92.5 | 2.5 | 50 | 2.40 |
| 35 | do Watertown, | 5.6 | 5.5 | 1.9 | 1.3 | 1.1 | 84.6 | 4.6 | 92 | 2.27 |
| 36 | do Halifax, | 3.3 | 2.7 | 0.3 | | 0.8 | 92.9 | 1.0 | 20 | 2.45 |
| 37 | do Cambridge, | 2.8 | 3.5 | 1.8 | | 0.2 | 91.7 | 2.6 | 52 | 2.45 |
| 38 | do Taunton, | 4.7 | 2.4 | 1.8 | | 0.8 | 90.3 | 1.8 | 36 | 2.44 |
| 39 | do Attleborough, east part, | 2.0 | 4.1 | 0.5 | | 0.6 | 92.8 | 2.8 | 56 | 2.48 |
| 40 | do do west part, | 2.5 | 6.6 | 1 9 | | 2.0 | 87.0 | 3.7 | 74 | 2.21 |
| 41 | Argillaceous Slate—Lancaster, | 5.0 | 4.5 | 4.6 | | 0.9 | 85.0 | 5.6 | 112 | 2.25 |
| 42 | do Sterling, | 6.1 | 4.6 | 1.8 | | 0.5 | 87.0 | 2.6 | 52 | 2.32 |
| 43 | do Townsend, | 6.2 | 5.0 | 1.0 | | 1.0 | 86.8 | 3.5 | 70 | 2.31 |
| 184 | Argillaceous Slate Soil, uncultivated—Lancaster, | 7.9 | 3.9 | 2.0 | | 1.0 | 85.2 | | | |
| 183 | do Boston Corner, | 4,0 | 7.3 | 2.5 | 3.0 | 1.0 | 82.2 | | | 2.35 |
| 44 | Limestone, (Magnesian,)—Marlborough, | 4.4 | 0.5 | 1.4 | | 2.0 | 91.7 | 3.0 | 60 | 2.43 |
| 45 | do Lanesborough, | 3.0 | 0.8 | 1.1 | | 4.2 | 90.9 | 3.6 | 72 | 2.39 |
| 46 | do Great Barrington, | 3.6 | 0.5 | 1.7 | | 5.0 | 89.2 | 3.5 | 70 | 2.56 |
| 47 | do Adams, | 2.2 | 0.4 | 1.5 | | 3.3 | 92.6 | 2.8 | 56 | 2.46 |

* This remarkable soil will receive further notice on a subsequent page.

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 192 | Limestone Soil, Saddle Mt. Adams, | 0.7 | 3.3 | 0.1 | 1.5 | 0.6 | 93.8 | | | 2·58 |
| 189 | do Richmond, | 2.6 | 2.1 | 0.8 | 0.8 | 0.8 | 92.9 | | | 2.39 |
| 190 | do South Lee, uncultivated, | 2.1 | 2.3 | 0.6 | | 0.7 | 94.3 | | | |
| 191 | do Egremont, | 1.4 | 1.5 | 1.8 | | 0.7 | 94.6 | | | 2.46 |
| 48 | do Williamstown, | 3.1 | 2.0 | 2.8 | | 0.6 | 91.5 | 5.5 | 110 | 2.39 |
| 49 | do Stockbridge, | 2.3 | 5.2 | 3.9 | | 0.7 | 87.9 | 6.0 | 120 | 2.45 |
| 50 | do Pittsfield, | 5.4 | 5.3 | 1.0 | | 0.7 | 87 6 | 3.0 | 60 | 2.39 |
| 51 | do Sheffield, | 2.7 | 4.2 | 1.8 | 0.8 | 0 5 | 90.0 | 5.1 | 102 | 2.27 |
| 52 | do W. Stockbridge, | 4.0 | 5.2 | 1.0 | 3.2 | 1.6 | 85.0 | 4.5 | 90 | 2.39 |
| 53 | Mica Slate Soil—West Boylston, | 6.0 | 5.1 | 0.9 | | 0.6 | 87.4 | 4.2 | 84 | 2.31 |
| 54 | do Webster, | 5.5 | 3.1 | 1.3 | | 1.0 | 89.1 | 5.5 | 110 | 2.31 |
| 55 | do Lunenburg, | 5.0 | 3.4 | 0.8 | | 1.1 | 89.7 | 4.3 | 86 | 2 29 |
| 56 | do Stockbridge, Mt. | 3.0 | 5.5 | 0.2 | | 1.5 | 89.8 | 5.3 | 106 | 2.40 |
| 57 | do Chester Village, | 6.0 | 3.5 | 1.5 | | 1 5 | 87.5 | 4.7 | 64 | 2.41 |
| 58 | do Bradford, | 6.5 | 6.8 | 2.0 | | 1.2 | 83.5 | 6.5 | 130 | 2.26 |
| 59 | do West Newbury, | 3.0 | 5.5 | 3.5 | | 1.0 | 87.0 | 4.8 | 96 | 2.37 |
| 60 | do Methuen, | 2.9 | 2.2 | 1.5 | | 0.6 | 92.8 | 0.9 | 18 | 2.53 |
| 61 | do Pepperell, | 3 8 | 7.0 | 1.6 | | 0.7 | 86.9 | 6.2 | 124 | 2.27 |
| 62 | do Norwich, | 4.1 | 4.3 | 1.2 | | 0.6 | 89.8 | 5.3 | 106 | 2.36 |
| 63 | do Conway, | 2.0 | 4.5 | 1,7 | | 1.1 | 90.7 | 3.2 | 64 | 2.53 |
| 181 | do uncultivated Russell, | 3.8 | 6.0 | 2.7 | | 0.5 | 87.0 | | | |
| 182 | do West Newbury, uncultivated, | 5.9 | 5.7 | 3.0 | | 0 9 | 85.5 | | | |
| 64 | Talcose Slate Soil—Chester, west part, | 1.5 | 2.1 | 3.1 | | 1.0 | 92.3 | 3.1 | 62 | 2,54 |
| 65 | do Charlemont, | 3.8 | 2.2 | 1.4 | | 0 6 | 92.0 | 3.5 | 70 | 2.45 |
| 195 | do uncultivated Becket, | 8.5 | 4.7 | 3.7 | | 1.1 | 82.0 | | | |
| 194 | do Rowe, | 4.1 | 4.6 | 2.5 | | 1.6 | 87.2 | | | 2.35 |
| 196 | do Mount Washington, | 2.6 | 4.7 | 1.7 | 2.0 | 1.5 | 87.5 | | | 2.33 |
| 66 | Talco-micaceous Slate—Florida, uncultivated, | 3.2 | 8.4 | 2.4 | | 2.0 | 84.0 | 5.8 | 116 | 2.35 |
| 67 | do Hancock, | 6.2 | 5.8 | 1.5 | | 1.0 | 85.5 | 2.3 | 46 | 2.31 |
| 68 | Gneiss Soil—Tewksbury, | 4.3 | 3.9 | 1.2 | | 0.8 | 89.8 | 3.5 | 70 | 2.41 |
| 69 | do Stow, | 4.0 | 3.0 | 2.0 | | 1.0 | 90.0 | 3.8 | 76 | 2.41 |
| 70 | do Bolton, | 4.6 | 3.4 | 2.1 | | 0.9 | 89.0 | 3.8 | 76 | 2.40 |
| 71 | do Uxbridge, | 2.6 | 3.0 | 2.9 | | 0.9 | 90.6 | 3.5 | 62 | 2.36 |
| 72 | do Mendon, | 2.6 | 2.5 | 2.4 | | 0.7 | 91.8 | 3.4 | 68 | 2.51 |
| 73 | do Tyngsborough, | 4.5 | 1.8 | 0.6 | | 0 6 | 92.5 | 2.6 | 52 | 2.45 |
| 74 | do Holden, | 3.9 | 4.7 | 1.4 | | 1.4 | 88.6 | 5.0 | 100 | 2.37 |
| 75 | do Dudley, | 4.0 | 4.6 | 1.9 | | 0.7 | 88.8 | 5.3 | 106 | 2.35 |
| 76 | do Templeton, | 5.2 | 4.1 | 2.7 | | 0.5 | 87.5 | 5.1 | 102 | 2.26 |
| 77 | do Rutland, | 7.1 | 5.3 | 1.9 | | 1.2 | 84.5 | 6.5 | 130 | 2.27 |
| 78 | do Westminster, | 5.3 | 3.8 | 2.2 | 3.0 | 0.7 | 85.0 | 4 6 | 92 | 2.26 |
| 79 | do Royalston, | 6.0 | 3.6 | 1.9 | | 0.6 | 87.9 | 5.4 | 108 | 2.27 |
| 80 | do Fitchburg, | 5.4 | 3.3 | 1.0 | 2.1 | 0.7 | 87.5 | 3.4 | 68 | 2.44 |
| 81 | do Petersham, | 5 7 | 4.8 | 2.4 | | 0.4 | 86.7 | 4.5 | 90 | 2.36 |
| 82 | do New Braintree, | 6.0 | 6.3 | 1.7 | | 0.8 | 85.2 | 6.7 | 134 | 2.34 |
| 83 | do Palmer, | 5.7 | 2.7 | 2.1 | | 0.6 | 88.9 | 2.6 | 52 | 2.49 |
| 84 | do Enfield, | 7.2 | 4.9 | 2.5 | | 1.0 | 84.4 | 6.4 | 124 | 2.29 |
| 85 | do New Salem, | 3.2 | 2.7 | 1.5 | | 0 7 | 91.9 | 3.7 | 74 | 2.44 |
| 86 | do Leverett, | 3.3 | 3.7 | 2.8 | | 0.7 | 89.5 | 4.4 | 88 | 2.49 |
| 87 | do Hardwick, | 6.3 | 3.3 | 2.1 | | 0.6 | 87.7 | 4.9 | 98 | 2.36 |
| 88 | do Ware, | 5.3 | 0.7 | 1.9 | | 0.6 | 91.5 | 2.3 | 46 | 2.58 |
| 89 | do Grafton, | 4.5 | 3.5 | 2.1 | | 0.6 | 89.3 | 5.4 | 108 | 2.39 |
| 90 | do Brimfield, | 5.3 | 2.1 | 1.0 | | 0.4 | 91.2 | 3.7 | 74 | 2.46 |
| 91 | do Leicester, | 3.9 | 2.9 | 2.8 | | 1.3 | 89.1 | 5.2 | 104 | 2.48 |
| 92 | do Otis, | 4.7 | 5.4 | 1.8 | | 1.1 | 87.0 | 6.0 | 120 | 2.34 |
| 93 | do Becket, | 8.3 | 2.4 | 2.9 | | 1.1 | 85.3 | 6.0 | 120 | 2.27 |
| 186 | do Sandisfield, | 3.2 | 3.3 | 2.5 | 2.8 | 1.5 | 86.7 | | | 2.32 |
| 185 | do Tolland, | 5.2 | 3.8 | 3.9 | | 1.0 | 86.1 | | | 2.28 |
| 187 | do Northfield, South Farms, | 1.3 | 3.0 | 1.5 | | 1.0 | 93.2 | | | 2.34 |
| 94 | do Buckland, | 5.4 | 2.0 | 2.1 | | 0.7 | 89.8 | 2.8 | 56 | 2.51 |
| 95 | do Wareham, | 2.0 | 0.6 | 1.2 | | 0.4 | 95.8 | 0.9 | 18 | 2.68 |
| 96 | do Sturbridge, | 5.1 | 3.7 | 2.3 | | 0.4 | 88.5 | 2.7 | 54 | 2.50 |
| 97 | do Brimfield, not cultivated, | 0.6 | 3.8 | 1.1 | | 0.5 | 94.0 | 3.7 | 74 | 2.60 |
| 98 | do West Brookfield, not cultivated, | 1.5 | 5.1 | 1.6 | | 0.5 | 91.3 | 4.7 | 94 | 2.68 |
| 99 | do Oakham, | 4.8 | 2.2 | 1.4 | | 0.3 | 91.3 | 3.0 | 60 | 2.55 |
| 100 | do Athol, decomposing Gneiss, | 0.3 | 5.3 | 2.0 | | 0.3 | 92.1 | 3.0 | 60 | 2.60 |
| 101 | Granite Soil—W. Hampton, | 1.2 | 4.0 | 1.6 | | 0.8 | 92.4 | 2.2 | 44 | 2.60 |

| No. | NAME AND LOCALITY OF THE SOIL. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Carbonate of Lime. | Phosphates. | Silicates. | 100 grains heated to 300° F. absorbed in 24 hours. | Absorbing Power in Proportional Numbers. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|---|
| 102 | Granite Soil, Concord, - - - - | 7.1 | 2.0 | 1.6 | | 0,5 | 88.8 | 2.5 | 50 | 2.50 |
| 103 | do Duxbury, - - - - | 4.0 | 2.0 | 0.8 | | 0.7 | 92.5 | 2.4 | 48 | 2.43 |
| 104 | do Andover, - - - - | 5.1 | 7.5 | 1.6 | | 0.6 | 85.2 | 4.4 | 88 | 2.29 |
| 105 | Sienite Soil—Lynnfield, - - - - | 5.1 | 5.2 | 1.4 | | 0.6 | 87.7 | 4.4 | 88 | 2.29 |
| 106 | do Marblehead, - - - - | 5.1 | 5.0 | 2.7 | | 0.6 | 86.6 | 5.8 | 116 | 9.35 |
| 107 | do Manchester, - - - - | 6.5 | 3.4 | 0.8 | | 0.6 | 88.7 | 4.0 | 80 | 2 40 |
| 108 | do Gloucester, - - - - | 2.4 | 2.2 | 1.5 | | 0.3 | 93.6 | 2.8 | 56 | 2.25 |
| 109 | do Lexington, - - - - | 5.4 | 3.9 | 2.6 | | 0.6 | 87.5 | 6·5 | 130 | 2.24 |
| 110 | do Danvers, - - - - | 3.8 | 6.9 | 2.7 | | 0.7 | 85.9 | 5.0 | 100 | 2.34 |
| 111 | do Newbury, - - - - | 5.0 | 5.5 | 1.0 | | 0.5 | 88.0 | 5.3 | 106 | 2.36 |
| 112 | do Dedham, - - - - | 7.0 | 4.7 | 1.0 | | 1.3 | 86.0 | 6.2 | 124 | 2.24 |
| 113 | do Wrentham, - - - - | 5.6 | 5.6 | 0.8 | 0.4 | 1.5 | 86.1 | 3.6 | 72 | 2.43 |
| 114 | do N. Bridgewater, - - - | 2.2 | 5.9 | 2.5 | | 0.7 | 88.7 | 3.7 | 74 | 2.36 |
| 115 | do Weymouth, - - - - | 2.6 | 5.1 | 2.2 | | 0.6 | 89.5 | 4.0 | 80 | 2.35 |
| 116 | do Sharon, - - - - | 6.9 | 3.2 | 1.7 | | 0.5 | 87.7 | 3.2 | 64 | 2.32 |
| 117 | do Marshfield, - - - - | 1.6 | 2.9 | 1.1 | | 0.8 | 93.6 | 3.7 | 74 | 2.45 |
| 118 | do Abington, - - - - | 2.7 | 3.7 | 1.5 | | 0.8 | 91.3 | 2.7 | 54 | 2.46 |
| 119 | Porphyry Soil—Kent's Island, Newbury. - - | 5.7 | 4.6 | 3.3 | | 0.4 | 86.0 | 6.3 | 126 | 2.26 |
| 120 | do Medford, - - - - | 8.7 | 4.2 | 2.6 | | 0.8 | 83.7 | 6.6 | 132 | 2.17 |
| 121 | do Malden, - - - - | 5.2 | 4.1 | 3.5 | | 1.6 | 85.6 | 6.8 | 136 | 2.26 |
| 122 | do Lynn, - - - - | 4.3 | 3.5 | 1.8 | | 0.6 | 89.8 | 5.9 | 118 | 2.29 |
| 123 | Greenstone Soil—Ipswich, - - - | 2.8 | 9.4 | 0.7 | | 0 2 | 86.9 | 3.6 | 72 | 2.22 |
| 124 | do Woburn, - - - - | 7.7 | 4.6 | 1.3 | | 1.2 | 85.2 | 6.0 | 120 | 2.27 |
| 125 | do Deerfield, - - - - | 3.2 | 4.3 | 0.1 | 2.0 | 0.3 | 90.1 | 2.7 | 54 | 2.51 |
| 1[illegible]7 | do . New land never manured Belchertown. | 2.3 | 4.6 | 2.4 | | 1.0 | 89.7 | | | 2.35 |

## *Explanation of the preceding Table of Results with Remarks and Inferences.*

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Masschusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analyses: and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analyzed from the different varieties of our soils is sufficiently large, to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows.

| | | Soluble Geine. | Insoluble Geine. |
|---|---|---|---|
| Alluvium, | | 2.37 | 2.13 |
| Diluvial argillaceous soil, | | 3.87 | 4.73 |
| Do Sandy, | | 1.52 | 1.30 |
| Sandstone | do | 3.28 | 2.14 |
| Graywacke, | do | 3.60 | 4.00 |
| Argillaceous slate | do | 5.84 | 5.06 |
| Limestone, | do | 2.88 | 3.51 |
| Mica slate | do | 4.10 | 5.10 |
| Talcose slate | do | 4.43 | 4.64 |
| Gneiss | do | 4.40 | 3.45 |
| Granite | do | 4.05 | 3.87 |
| Sienite | do | 4.40 | 4.50 |
| Porphyry | do | 5.97 | 4.10 |
| Greenstone | do | 4.00 | 5.72 |

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except the very sandy diluvial ones. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure them yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others: so that taking all things into the account, they are among the most valuable of our soils: and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic

matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve: but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named: and hence we ought not to expect a perfect agreement in the results of the two methods.

The two next columns in the Table contain the sulphate and carbonate of lime, and the third column the phosphates generally: in most cases probably it is the phosphate of lime: but sometimes of alumina and perhaps of other bases. I have already described the infrequency of the carbonate of lime in our soils: but it will be seen that I found the sulphate of lime as well as phosphates in every soil analyzed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphates have generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is not possible that in all the soils which I have analyzed, such was their origin, for 13 of them have never been cultivated. And there is strong reason to believe, that phosphates are a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana, that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent. of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent. of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent. phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphates of lime, not only in the grain but in the straw, and often in the state of superphosphates. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid.* Can it be that, owing to certain electrical influ-

ences of the air, in particular seasons, lime is not secreted by the plant to neutralize the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphates do we thus annually draw from the soil? Cotton gives one per cent. ashes, of which 17 per cent. is composed of phosphate of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent. of phosphate of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent. phosphate of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphate of lime, in powder, is decomposed by growing leaves, the lime being liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphate of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphate of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent. phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron: 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 ashes of | Bass wood | 5.4 phos. lime, | | 3.3 phos. iron. | | |
| " | Birch | 7.3 | " | 1.25 | " | |
| " | Oak wood | 1.8 | " | | | |
| " | Alder coal | 3.45 | " | 9.00 | " | |

"These are the calculated results from Berthier's very accurate analyses: and those very curious crystals—detected in some plants—the "*raphides*" of De Çandolle, are some of them bibasic phosphates of lime and magnesia. Phosphate of iron, we know, is common in turf; and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphate of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphates, which we now find in cultivated fields, rescued from the forest, is due to our manure:—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14,: biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphate and phosphate of lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphate, 0.12 carbonate, and 0.12 sulphate of lime. Now, a bushel of

green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent. are soluble. Of this portion only 0.95 can be considered as soluble geine."

## *Western Soils.*

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were take from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.*

| No. | | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Carbonate of Lime. | Silicates. | Water of Absorption. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 198 | Rushville, Illinois, | 7.4 | 2.5 | 3.4 | 0.6 | 1.5 | 84.6 | 6.3 | |
| 199 | Sangamon co., do | 4.9 | 5.6 | 1.2 | 0.4 | 1.3 | 86 6 | 6 3 | |
| 200 | Lazelle county, do | 7.6 | 13 8 | 1.4 | 0.4 | 3.3 | 73.5 | 9.5 | Apparently never cultivated. |
| | Peoria county, do | 3.1 | 4.8 | 3.5 | 1.0 | | 87.6 | 5.7 | |
| 201 | Scioto Valley, Ohio, | 4.5 | 6.7 | 2.1 | 0.9 | 2.8 | 83.0 | 5.3 | Cultivated 14 years without manure |

The above soils are evidently of the very first quality: the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been culti-

* The analysis of four of these soils in the dry way by alkali has been already given with the salts from the above Table.

vated: and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts; viz., to provide for the yearly supply of more geine and more salts.

### *Mode of testing the Phosphates obtained by Dr. Dana's Rules.*

If the results which I have given as to phosphates in soils be admitted as correct, they will settle the question, when taken in connection with Dr. Dana's reasoning, as to the very wide if not universal diffusion of this class of salts. But since Dr. Dana's rules imply that the process for obtaining them may also produce a little iron, and perhaps alumina, the enquiry arises, whether in some instances at least, what I have given as phosphates, may not in fact be only iron and alumina. I determined, therefore, to test some of these results. In doing this, I have followed two methods, appended by Dr. Dana to his rules already given for the analysis of soils; but which were not inserted in my report of 1838. I give them in his own language.

"As to the best mode of detecting phosphates in soils, (I say *phosphates*, because the third rule of analysis includes all phosphates under phosphate of lime,) there are two modes which I would suggest.

"1. Having reduced the analysis to the point at which the 3d rule estimates the phosphate of lime, dissolve that in pure acetic acid. Treat the solution with sulphuretted hydrogen to separate any iron and manganese; warm it to drive off the excess of sulphuretted hydrogen, and then treat the clear solution with acetate of lead. Phosphate of lead falls if any phosphoric acid is present—The only source of error is in the presence of sulphate of lime. The rule supposes that to be removed. If you doubt, collect the supposed phosphate of lead; dry, fuse on charcoal, in the outer flame of the blowpipe: phosphate of lead *crystalizes* as it cools. So says Berzelius and he considers this test infallible."

"2. Fuse the phosphate of lime of Rule 3 of analysis, with carbonate of soda. Dissolve in water, saturate the solution with nitric acid. If a precipitate occur it is subphosphate of alumina. Treat the clear solution with nitrate of silver; a *yellow* precipitate occurs if phosphoric acid is present. The lime in both cases may be separated by an oxalate as usual."

It is possible that a phosphate may exist in a soil and yet not be detected by either of these rules. Hence in a doubtful case, it may be well to fuse some of the finer part of the soil with alkali, and then treat the resulting solution as in the second of the above rules.

I applied the above rules to several of the phosphates obtained from soils, with the following results.

| No. of the Soil. | Amount of the Phosphates used. | Action of acetate of Lead on the Acetic Solution. | Action of the Oxalate of Ammonia. |
|---|---|---|---|
| 192 | 0.41 | Precipitate | No trial |
| 189 | 0.40 | Do. | Do. |
| 183 | 1.33 | Do. | Precipitate slight |
| 186 | 1.13 | Do. | Do. larger |
| 196 | 1.03 | Do. | Do. small |
| 176 | 1.30 | Do. | Do. larger |
| 179 | 0.90 | Do. | Do. |
| 178 | 0.09 | Do. | Do. |
| 191 | 0.60 | Do. | Do. |
| 185 | 1.50 | None | Do. |
| 2d. Trial | 1.00 | Do. | Do. |
| 187 | 1.18 | None | Do. |
| 2d. Trial | 1.04 | Do. | Do. |
| 203 | 0.81 | Precipitate | Do. slight |
| 204 | 0.12 | Do. | Do. Do. |

Although Nos. 241, and 242 gave no precipitate with acetate of lead, I was led to suspect that the phosphates might exist, but had become nearly insoluble by ignition; as is often the case (*Rose's Analytical Chemistry by Griffin, p.* 261). Indeed, in nearly all the cases described above, a considerable residuum remained after digestion in acetic acid. I determined, therefore, to attack Nos. 241, and 242 with several others, by means of carbonate of soda, and the results are given in the following table; which it will be seen confirm my suspicions as to the presence of phosphoric acid in Nos. 241, and 242.

| No. of the Soil. | Effect of Saturation with Nitric Acid | Action of Nitrate of Silver. |
|---|---|---|
| 185 | Slight Cloudiness | Yellow Precipitate—abundant. |
| 187 | Do. | Do. Do. |
| 194 | Do. | Do. Do. |
| 197 | Do. | Do. only slightly yellow |
| 179 | Do. | Do. very yellow |

I cannot see why the above trials do not satisfactorily show the presence of the phosphate of lime in all the 15 soils and marls that were operated upon; and the probable presence of subphosphate of alumina in five of them: yet as to this last point, I do not feel very confident, because the precipitates were very slight. These results were so satisfactory, that I did not think it necessary to subject any more soils to a similar process. I will not say that I should have found phosphoric acid in every soil, whose analysis I have given: but I feel justified in inferring from these trials, that it does exist in nearly every one of them. If any one should make use of Dr. Dana's rules for the analysis of soils, and are in doubt as to the phosphates, the rules above given will enable him to settle the question.

It is certain however, that Dr. Dana's method of determining the presence and amount of the phosphates in a soil by muriatic acid, does usually separate some iron, which is mixed with the phosphates; for in most cases, the results are more or less colored by the per oxide of iron. Possibly also a little alumina may thus be separated, yet I think this so minute in quantity that it need not be taken into the account. It becomes, however, an interesting enquiry, how large a proportion of iron is mixed with the phosphates. I made a few trials to determine this point. It has been already stated, that only a part of the phosphates were soluble in acetic acid. The insoluble residuum was digested in muriatic acid, which probably took up all the iron, although a small insoluble portion of matter still remained. The iron was precipitated by ammonia, and the following is the result.

The amount of matter left undissolved by acetic acid in the phosphate from Nos. 189, 183, 186, 196, 203, 204, and 176, (amounting to 6 grains) was 3.76 grains; which digested in nitromuriatic acid, left a residum of 0.46 grains; and ammonia threw down from the solution 2.22 grains. This divided by 7, gives 0.31 for the amount of iron in each soil; or about one third part of the supposed phosphates. The phosphates from the following soils were tried separately by muriatic acid and ammonia, with the following results.

| No. | Amount of Phosphates. | Residuum from Acetic Acid. | Peroxide of Iron. |
|---|---|---|---|
| 179 | 0.90 | 0.73 | 0.1 |
| 178 | 0.09 | 0 04 | 0 0 |
| 191 | 0.60 | 0.43 | 0.1 |
| 185 | 1.50 | 0.93 | 0.1 |
| 187 | 1.18 | 1.00 | 0.23 |

The amount of iron in these last examples is much less than in the first; yet taking all things into consideration, I should be disposed to reduce the amount of the phosphates, given in the general table of analysis, one third; and I think we may safely calculate that the residual numbers will not at least exceed the actual amount of the phosphates in the soils of Massachusetts.

### *Combinations of Phosphoric Acid in Soils.*

It is rendered probable by the preceding results, as well as by general considerations, that phosphate of lime is the most usual form assumed by phosphoric acid in soils. But Dr. Dana has come to the conclusion, founded upo nsome analytical trials, that a large portion of the phosphoric acid exists in combination with alumina. He says, "In the few trials I made, I found

subphosphate of alumina in the soils. Phosphate of alumina is so very difficult to separate and distinguish from pure alumina, that I have no doubt the absence of phosphoric acid in soils has been here overlooked. The subject needs further investigation." In a recent analysis of a rich soil from the state of Maine, Dr. C. T. Jackson has discovered 3 per cent. of subphosphate of alumina. (*Third Report on the Geology of Maine, p.* 150.)

The importance of the question whether phosphates exist generally in our soils, must plead my apology for dwelling so long upon it. If the views here advanced should prove true, it will be an important step gained in agricultural chemistry. If they prove false, I shall have the consolation of knowing that I have erred on a very difficult subject: and that I am in good company. I expect and wish that my views should not be received without thorough examination. Nor shall I be offended if the result at which I have arrived should be imputed to errors of analysis; provided chemists will themselves respeat these experiments. I would remark however, that in the application of Dr. Dana's rules for detecting the phosphates, it seems hardly possible for a mere tyro to commit much error, provided he possess pure muriatic acid;—a point which I endeavored to make sure by distilling it with a Wolf's Apparatus. To cause this acid to pass through a soil upon a filter, so as to get a transparent solution, does not surely require much skill: and then nothing remains but to evaporate this solution to dryness, and treat the residuum with water: so that it seems hardly possible to impute the existence of an insoluble residuum to any error in analysis.

### *Importance of Calcareous Matter in Soils.*

It will be seen from the numerous analyses of Massachusetts soils that have been given, that lime in some form, and generally in several forms, exists in them all. Indeed, since this substance is found at least as a silicate in nearly all the rocks, we might expect it in all soils. Besides, vegetation itself, when it decays, furnishes a supply. The fact of this universal diffusion of lime is a presumptive argument, as has been already maintained, in favor of its importance, if not necessity, for the production of healthy vegetation. And numerous experiments that have been made, especially in Europe, confirm this opinion. For in a vast majority of cases, the addition of lime, either as quicklime; or as marl, or ground limestone, which are carbonates; or as gypsum, which is a sulphate; or as pulverized bones, which are phosphate; increases the fertility of land: and after a few years it becomes desirable to add another quantity. From hence it follows, that the lime in a soil is gradually used up, like the geine, by entering into the composition of the plants, growing upon it. And in such soils as those of Massachusetts,

probably all the lime would ere this have been exhausted, did it not exist in a state of such intimate combination, as to be extracted with difficulty. The rootlets of plants probably possess the power of decomposing the geate, and even the silicate of lime; and every other earthy combination most likely, by means of galvanic agency. It seems, however, that only a very small quantity of lime is essential to supply the immediate wants of the plant; and a soil that is half lime does not appear to be more productive than one containing 2 or 3 per cent.; though the former will retain its fertility a greater length of time. Lime also seems in many instances to exert an important influence in bringing geine into a proper state, to be taken up by the plants; as will be more fully shown farther on.

It is difficult to make a man not conversant with chemistry, realize that a crop may often fail upon his land from the absence of one or two per cent. of some substance, which, when present, analysis only can detect. Yet the chemist will not hesitate to admit the truth of this position: and the ingredient, whose presence is so important, may sometimes be lime. As this is unperceived by the farmer however, and as the state of the weather and other more common causes of the failure of crops are obvious, it is apt in all cases to be referred to them.

The numerous instances in which lime applied to land has seemed to produce no effect, has led some to infer that this substance is of no use upon soils. By such reasoning it would be easy to prove that every kind of manure is useless: for there is not one of them that does not sometimes prove useless, perhaps not as often as lime does, yet the principle of reasoning involved is the same in both cases:-and it is a faulty one. For in both cases we can point out reasons why failures should sometimes occur. In respect to manures, these usually result from the state of the weather, using that term in its most extended sense. But in respect to lime, the failure may result from the fact, that the soil already contains enough of that substance for present use; or from the fact that there is no acid in the soil to be neutralized, and no vegetable matter in a state to be beneficially acted upon. Then again, it ought to be recollected that lime rarely produces any very visible effect for a year or two; and such may be the amount already in the soil, and such the state of the geine, that even 4 or 5 years are not long enough to prove that the lime does no good, for if vegetation does exhaust the lime in soils, the time will come, when that which has been artificially supplied will come into use; although from the nature of the case, it might be impossible to prove when this took place, because we know not when that natural to the soil would become exhausted. To be sure, in such cases the application of lime would be to benefit posterity, rather than ourselves; and the application might as well be delayed.

There may be other causes why lime seems to produce no effect upon soils—causes, which in the present state of our knowledge on the subject, we may be unable to understand: nor do I believe that the agricultural chemist, by the aid of the most accurate analysis, can in all cases certainly predict that lime will, or will not, be beneficial. He may be tolerably confident that a highly calcareous soil does not need it;—as experience proves in England. And if we adopt the views of Dr. Dana, which I shall shortly introduce, as to the mode in which lime acts upon soils, we may go a step farther; and say that it will not produce any striking effects unless there be acid in the soil to be neutralized, or organic matter in such a state as to be converted into a geate, or into soluble geine. Beyond this we can scarcely go: and hence experiment is the only sure mode of determining the effect of lime upon our soils.

Some maintain, indeed, that the quantity of lime in a soil remains always the same. But is it not certain that most vegetables contain lime. Now if these are suffered to decay upon the land, or an equivalent supply is furnished by manure, the position is correct. But when crops are removed, as is usually the case, in far greater quantity than the manure returned, whence is the deficiency of lime thus carried off to be supplied? It cannot come from the atmosphere, nor from rain water; though the water of springs usually contains a small quantity of sulphate of lime. Or if no lime is abstracted from the soil, how can it need a fresh application of this substance after an interval of a few years; as we know to be the case where lime is found to be beneficial once?

But after all, the grand enquiry is, what upon the whole has been the effect of the application of lime upon soils not already saturated with it? In Great Britain, where the experiment has been made under the most enlightened superintendence and on a most extended scale, the result is very decided. "Lime," says one of the writers of that country, "has long been applied by British husbandmen, as a stimulus to the soil; and in consequence of such an application, luxuriant crops have been produced, even upon soils of apparently inferior quality, and which would have yielded crops of trifling value had this auxiliary been withheld. In fact the majority of soils cannot be cultivated with advantage till they are dressed with lime; and whether considered as an alterative, or as a stimulant, or as a manure, it will be found to be the basis of good husbandry, and of more use than all other manures put together. Wherever lime has been properly applied, it has constantly been found to prove as much superior to dung, as dung is to the rakings of the roads or the produce of a peat mire."—*Morton on the Nature and Properties of Soils, &c." London*, 1838. *p.* 182.

Now suppose that the comparatively few imperfect experiments on

the use of lime which have been made in this country had nearly all failed to prove lime beneficial, should we be justified in infering that British agriculturists have so long been mistaken? Ought we not rather to infer, that we had not yet discovered the proper mode of applying lime, which in our climate may need to be applied in a manner somewhat modified, though this is not very probable. But what in fact is the experience of American farmers on this subject? The same, I answer, as in England, in France, and other European countries; viz, that in a great majority of instances lime is an excellent manure, though sometimes it seems to produce no effect, from causes not always discoverable. Lime, however, has not been as yet very extensively employed in our agriculture; partly from the dearth of the material in the older settlements, and partly from there being less need of it in a new country, where the land has been growing richer and richer for ages. In many parts of New York, Pennsylvania, Virginia, &c. however, lime is extensively employed. But in Massachusetts its use as a manure has been very limited. Even in Berkshire County, where the carbonate is so abundant, but few experiments have been made on this subject. In some other parts of the State insulated but successful experiments have been made with lime, which I shall mention more particularly when I come to describe our marls and limestones. The sulphate of lime has been used more extensively, I apprehend, in Massachusetts, and with more marked success, than lime in any other form: and the phosphate, or bones ground into powder, is beginning to be used in the vicinity of Boston very successfully. In short, it must be strong prejudice, or a defective philosophy, which leads any one to decry the use of lime upon soil, because his own experiments, or those of his neighbors, have failed. I acknowledge that the few trials which I have made with caustic lime have had little apparent success. But how unphilosophical hence to infer that the long and enlightened experience of Europeans, and much in our own country, is to go for nothing!

It is a very prevalent opinion in New England, that lime is especially necessary for the successful cultivation of wheat: that is, more necessary than for most other crops. Now analysis leads to an opposite conclusion: for while only 37 per cent. of lime exists in the ashes of wheat, 66 per cent. is found in potatoes. Nor have I seen any evidence that wheat will not grow as well as potatoes without the application of lime: and since our citizens have turned their attention for several years past to the cultivation of wheat, many facts in support of this opinion have come out. According to the views that have been advanced, the grand point is to bring the geine of the soil into a proper state for immediate nourishment; and ashes would probably accomplish this more effectually than lime. The best crop of wheat raised in Amherst, in the year 1838, was grown upon the soil not limed, derived from coarse granite,

whose feldspar probably yielded potassa, a substance eminently adapted to render the geine soluble.

## *Nature of Geine.*

From the statements that have been made, it appears that Sprengel, Boullay, and Berzelius, regard Geine, or *Humus*, as a distinct and peculiar compound, made up chiefly of oxygen, hydrogen, carbon and nitrogen. This view of the subject, however, has been strenuously opposed by M. F. V. Raspail, a French chemist of distinction, in his New System of Organic Chemistry, translated and published in London in 1834. He denies the existence in vegetables and soils of any such proximate principle as geine, and says, "it will be easy to see that all these phenomena, (described by Berzelius and others,) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to Ulmin, are essentially nothing but a developement of carbon! He must of course maintain that this carbon is never dissolved, but only suspended in a fluid! Plants he conceives are nourished almost entirely by carbonic acid; and he says that "possibly by supplying artificially to the plant the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with." These reasonings of Raspail did not lead Berzelius to change his views respecting geine; but rather to maintain more decidedly his previous opinions in a subsequent publication.

More recently some chemists have advanced the opinion that soluble geine is composed of at least three vegetable acids;—the crenic, the apocrenic, and ulmic; with a black matter called *earthy extract*; and that insoluble geine is ulmic acid mingled with undecomposed vegetable remains. *(American Journal of Science, Vol.* 36. *p.* 369.*)* Dr. Charles T. Jackson has made numerous experiments on this subject of late, and, as stated in a letter, he thinks he has "satisfactorily proved that there is no such thing as *geine;* but the substances which have been mistaken originally by Berzelius, and subsequently by Dr. Dana, for a simple substance, really consist of a compound of the two new acids (crenic and apocrenic) discovered by Berzelius shortly after the publication of his first account of Geine and Apothem." These exist "with occasionally a small proportion of phosphoric acid and perhaps also of oxalic acid: these acids often being in combination with calcareous, magnesian, manganesian and ferruginous bases."

I have not thought it necessary for me to go in this place into a discussion of these various opinions respecting the nature of geine. As to that of Raspail, who supposes it to be mere carbon diffused not dissolved in water, &c. I can hardly believe it will be adopted by any one who has gone through many processes with this substance; and has seen especially how decidedly it is often precipitated by reagents. If its mixture with liquids be not a real solution, I can hardly expect to distinguish a solution in any case. As to those views which suppose geine to be a mere mechanical mixture of crenic and apocrenic acids, (to lay aside all doubts about their distinct existence,) I would merely enquire, whether the occurrence of these acids in the organic matter of soils, proves that geine has no distinct existence?* Why may it not be a compound of these, and perhaps other acids, and other ingredients? Does not the fact that these two acids are uniformly present in soluble geine, render it probable that they do enter into chemical combination to form such a compound substance? If I understand Dr. Dana's views of the nature

* An excellent paper on the Physical Properties of Soils has lately appeared in the first Volume of the Journal of the English Agricultural Society, by Professor Schuhler of Tübingen. He gives the composition of 28 varieties of soil, analyzed by himself, Prof. Gieger, and Dr. Sprengel, under the terms, *Sand: Clay, or Deposite: Humus;* and *Volatile Matter.* But for some reason or other, he makes no allusion to crenic or aprocrenic acid, nor to any of the new views respecting geine. Except what this fact would indicate, I confess myself unable to say how far these views have been adopted by scientific men in Europe.

of geine, they are not inconsistent with such a supposition; though he has said but little in his communications to me on this point. But in a letter to Mr. Colman, given in his Second Agricultural Report, p. 165, he has given an analysis of 3.6914 grains of soluble geine, as follows:

| | |
|---|---|
| Geine, | 1.9258 |
| Alumina and Oxide of Iron, | .7715 |
| Phosphoric Acid, | .2315 |
| Magnesia, | .3396 |
| Loss, | .4230 |
| | 3.6914 |

Dr. Dana adds: "I presume that the soluble geine of all soils is similarly constituted. All which I have examined affords these elements." Now if phosphoric acid, alumina, &c. may form elements of geine, why may not what is called *geine* in the above analysis, consist of crenic and apocrenic acids, in perfect consistency with Dr. Dana's views?

But suppose it be admitted that these various acids and oxides do not form chemical but only mechanical mixtures in the soil. Yet most scientific men will allow that they constitute that portion of the food of plants which is derived from the soil; and if Dr. Dana's rules of analysis will show us how much of them the soil contains, and what part is in a soluble state, or in a state in which it can be immediately taken up by the organs of plants; and what part is in an insoluble state, unfitted for immediate use; I really cannot see why those rules are not just as valuable, whether geine be a distinct compound, or whether it be composed of crenic, apocrenic, phosphoric, and oxalic acids, casually mixed together. If Dr. Dana's rules do not point out the best mode of accomplishing these objects, and any chemist will suggest a better one, I am sure no one will more cheerfully substitute the improved methods for those proposed in this report, than the author of them. But even though such improvements should be proposed, the credit will still belong to Dr. Dana, of having first suggested this mode of analysis; and of having at the very outset proposed rules remarkable for their simplicity and ease of application. They are such rules as could have been furnished only by one who was thoroughly conversant with the theory and manipulations of chemistry, whose life in fact had been devoted to the subject. They are indeed, suggested by Dr. Dana only as rules for the intelligent farmer: although some have understood them as intended for the accomplished analyst. And indeed, I believe them capable of so accurate an application that even such a man may find them of great benefit.

There is another point on which I conceive Dr. Dana to have been misunderstood. It has been thought that he would make geine the sole food of plants, and deny the current opinion that they have the power of absorbing carbonic acid from the atmosphere and perhaps from the soil. But I do not thus understand him. I suppose he means only, that geine is one of the sources—though a most important one—from which vegetables derive their nourishment; but not the only one. Nor would he deny probably—though here I speak without any certain knowledge—that plants may have the power, to a certain extent, of adapting themselves to their condition, so that when they cannot obtain nourishment in one mode, they may get the more in some other mode. Without such a principle I cannot see how all the phenomena of vegetable development can be explained.

## *Dr. C. T. Jackson's Mode of Analysis.*

It may be desirable to present a mode of analyzing soils, such as one would adopt who believes there is no such compound as geine; and that crenic and apocrenic acids exist in the soil in an insulated state. Dr. Jackson has adopted such a mode in analyzing the soils of Rhode Island;

which will appear in his report upon the geology of that state: and he has obligingly furnished me with a brief sketch of his method, which I now present in his own words.

"1. Dry the soil at a temperature a little above 212°; say 240° at the highest. Dry your filters at the same temperature.

"2. Take 100 grains, or if you please, 1000 grains of the soil, in its dry state, for the separation of the organic matters. Put this into a French green glass flask of 6 cz. size, and fill the flask up to the base of the neck, with a saturated solution of the carbonate of ammonia in distilled water. Digest the soil at 240°, or thereabouts, for 36 hours: or you may safely boil the whole. Decant upon a double filter: pour on another charge of carbonate of ammonia, and repeat the operation until the ammoniacal solution comes off colorless. Then wash out the whole contents of the flask upon the filter. Wash with hot water, until no trace of the ammonia is left: then dry the filter and its contents at 240° and weigh: the loss is the soluble vegetable matter. Burn the residue in a plantium crucible in the muffle: the loss is the insoluble vegetable matter.

"3. Take now your solution: acidulate it with pure acetic acid, and drop in a solution of the acetate of copper, or even a solution of pure crystalized verdegris. A brown precipitate will rapidly form, which is the apocrenate of copper. Let the solution stand over night in the drying closet, or some warm place: all the apocrenate will subside. This you may collect on a carefully counterpoised filter, and weigh when dried; or you may wash it in the jar repeatedly, and mixing it with a little distilled water, you may decompose it by a current of sulphureted hydrogen; which will throw down all the copper, and then you may separate the solution of apocrenic acid, evaporate to dryness slowly, (or over sulphuric acid under the air pump,) and weigh it by substitution. Next render your solution highly alcaline, by means of carbonate of ammonia: boil it to drive off the carbonic acid. Drop into it, when cold, acetate of copper in solution. A whitish green precipitate of crenate of copper falls, and will collect abundantly by letting the solution stand in a warm place over night. Collect your crenate and weigh it by the double counterpoised filters; or wash it and decompose it as you did the apocrenate, and you will have a straw colored solution of crenic acid. Evaporate to dryness over concentrated sulphuric acid, and weigh by substitution. The crenic acid looks like a varnish on the inside of the capsule. Dissolve and test it. You will frequently find in it crystals of phosphate of ammonia, also, from the phosphoric acid in the soil: and I have always found this acid in my analysis of peat. When you have obtained a pure crenate or apocrenate of copper, you may analyze it by the process of deutoxide of copper; or more simply, you may deflagrate it with nitre and separate the copper n the state of deutoxide and deduct it from the weight of the crenate employed, and you will have the quantity of the crenic acid. Acetate of lead throws down all the crenic and apocrenic acid from a slightly acidulated solution, made by carbonate of ammonia. Muriatic acid throws down apocrenic acid in brown flocks from the ammoniacal solution. Lime water does not throw down all the crenic acid: for the crenate of lime is highly soluble."

## *Silicates.*

When the geine and the salts that have been described, chiefly those of lime, have been extracted from a soil, the residue is mostly a compound of silica with alumina, iron, lime, magnesia, &c. usually called *Silicates,* because the silica is regarded as acting the part of an acid; although its compounds are not commonly denominated salts. These silicates occupy the eighth column of the preceding table of analyses; and their amount was

obtained by subtracting the geine and salts from 100. Concerning the nature of these silicates, I have nothing farther to add, to the extended remarks already made on this subject.

### *Power of Soils to absorb Water.*

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthern plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was at 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

### *Power of Soils to retain Water.*

It is well known that some soils will bear a drought better than others. This may be owing to three causes: 1. one soil may have more power to retain water than another: 2. one may absorb more water than another during the night: 3. one may have a subsoil less pervious to water than another. When these three causes combine, they may operate powerfully upon the ability of a soil to resist long continued drought. But when one operates differently from the others, they may in a measure neutralize one another. Hence it may be doubted whether direct experiments in the small way upon the power of soils to retain water, will give their real power. Yet since we have reason to believe the retaining power to be in direct proportion to the absorbing power, the forces above mentioned will rarely if ever act in opposition; and hence, I thought it might be desirable to perform some experiments on the subject. Those which I gave in my Report of 1838, were made in the

winter, and on different days, when the temperature and the dew point were different; so that they could not be directly compared. Hence I was led to repeat them with some variation, during the summer of 1839. I confess that I do not see what important results can be derived from them. But as they are the first trials of the kind with which I have met, they may be useful to compare with others that may be hereafter made: and therefore I shall detail them.

200 Grains of each soil were spread upon earthern plates of about 3 inches diameter; and the weight of the whole obtained. By means of a graduated dropping tube, 100 grains of water were added to each plate: when, at 9 o'clock A. M. June 25th. they were all at the same time exposed, in a situation sheltered from the wind, to the direct rays of an almost cloudless sun, for 3 1-2 hours; when all were removed to a dry room and weighed. The loss of weight is given in the second column in the annexed Table: the first column indicating the number of the soil which corresponds to those in the state Collection. During the following night the plates were exposed without removing the soils, to a cloudless atmosphere, and weighed in the morning. The gain is given in the third column. Next morning, June 26th, 100 grains of water were added to each plate, and the whole exposed as before, to the sun, from 8h. 30m. till 11 hours, when they were weighed as before, and the loss constitutes the fourth column. Remaining in a dry room till July 1st. they were again exposed without adding water, to the sun, from 11 to 3 o'clock and then weighed, and the loss constitutes the fifth column: although in this case, it will be seen, that there were numerous failures.

It will be seen from the above statement, that the third column shows the absorbing instead of the retaining power of the soils.

The following was the state of the thermometer and of Daniell's Hygrometer on the days when the experiments were made.

| | |
|---|---|
| June 25th. 1839. | |
| Thermometer at 9 hours A. M. | 72° |
| Dew Point at that hour | 58 |
| Thermometer at 12h. 30m. | 79 |
| Dew Point | 52 |
| Thermometer at 8 hours P. M. | 72 |
| Dew Point | 53 |
| June 26th. | |
| Thermometer at 8h. 30m. | 70° |
| Dew Point | 60 |
| Thermometer at 11h. A. M. | 75 |
| Dew Point | 58 |
| July 1st. | |
| Thermometer at 11h. A. M. | 77° |
| Dew Point | 64 |

## *Experiments on the Retaining Power of Soils.*

| No. | Loss of 200 grs. in 3 1-2 hours June. 25 | Gain at night | Loss in 2 1-2 hours June 26. | Additional loss in 4 hours July 1. |
|---|---|---|---|---|
| 1 | 100 | 5 | 100 | 6 |
| 2 | 96 | 7 | 98 | 8 |
| 3 | 93 | 6 | 99 | 7 |
| 4 | 100 | 7 | 105 | 3 |
| 5 | 102 | 8 | 103 | 6 |
| 6 | 100 | 5 | 103 | 4 |
| 7 | 99 | 8 | 101 | 2 |
| 8 | 103 | 8 | 105 | 4 |
| 9 | 99 | 9 | 101 | 8 |
| 10 | 102 | 9 | 105 | 5 |
| 11 | 100 | 7 | 105 | 3 |
| 12 | 101 | 7 | 97 | 10 |
| 13 | 100 | 7 | 101 | 8 |
| 14 | 102 | 8 | 102 | 8 |
| 15 | 101 | 5 | 103 | |
| 16 | 101 | 7 | 104 | |
| 17 | 101 | 7 | 104 | |
| 18 | 100 | 5 | 108 | |
| 19 | 95 | 6 | 107 | |
| 20 | 99 | 4 | 102 | |
| 21 | 101 | 6 | 109 | |
| 22 | 100 | 4 | 104 | |
| 23 | 88 | 5 | 109 | |
| 24 | 101 | 6 | 104 | |
| 25 | 101 | 4 | 108 | |
| 26 | 103 | | | |
| 27 | 102 | 9 | 101 | 8 |
| 28 | 101 | 7 | 104 | 5 |
| 29 | 100 | 7 | 97 | 12 |
| 30 | 102 | 10 | 105 | 5 |
| 31 | 101 | 10 | 108 | 4 |
| 32 | 98 | 11 | 108 | 5 |
| 33 | 102 | 12 | 103 | 9 |
| 34 | 100 | 11 | 103 | 9 |
| 35 | 82 | 14 | 102 | 14 |
| 36 | 101 | 9 | 104 | 6 |
| 37 | 97 | 12 | 108 | 4 |
| 38 | 101 | 12 | 107 | 5 |
| 39 | 101 | 11 | 106 | 7 |
| 40 | 101 | 13 | 102 | 13 |
| 41 | 92 | 13 | 105 | |
| 42 | 101 | | 104 | |
| 43 | 106 | | 112 | |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional loss in 4 hours. |
|---|---|---|---|---|
| 44 | 105 | 17 (?) | 112 | |
| 45 | 106 | 14 | 111 | |
| 46 | 103 | 13 | 100 | |
| 47 | 100 | 9 | 106 | |
| 48 | 102 | 9 | 100 | |
| 49 | 103 | 11 | 111 | |
| 50 | 102 | 8 | 105 | |
| 51 | 102 | 11 | 105 | 8 |
| 52 | 102 | 13 | 104 | 9 |
| 53 | 102 | 12 | 103 | 10 |
| 54 | 103 | 13 | 103 | 11 |
| 55 | 103 | 10 | 101 | 12 |
| 56 | 101 | 7 | 100 | 9 |
| 57 | 102 | 9 | 106 | |
| 58 | 104 | 15 | 105 | |
| 59 | 100 | 12 | 103 | |
| 60 | 102 | 8 | 108 | |
| 61 | 102 | 9 | 104 | |
| 62 | 101 | 8 | 100 | 4 |
| 63 | 103 | 14 | 108 | 5 |
| 64 | 104 | | 108 | 4 |
| 65 | 105 | 17 (?) | 105 | 9 |
| 66 | 114 | 13 | 107 | 6 |
| 67 | 104 | 12 | 108 | 4 |
| 68 | 96 | 5 | 110 | |
| 69 | 107 | 15 | 109 | 1 |
| 70 | 106 | 12 | 106 | 2 |
| 71 | 104 | 11 | 106 | 3 |
| 72 | 104 | 9 | 107 | 0 |
| 73 | 109 | 13 | 104 | 1 |
| 74 | 104 | 7 | 91 | 14 |
| 75 | 99 | 7 | 93 | 12 |
| 76 | 101 | 9 | 97 | 10 |
| 77 | 101 | 10 | 101 | 5 |
| 78 | 102 | 9 | 105 | 1 |
| 79 | 100 | 9 | 102 | 5 |
| 80 | 102 | 12 | 111 | 1 |
| 81 | 101 | 13 | 111 | 10 |
| 82 | 101 | 5 | 95 | |
| 83 | 104 | 9 | 107 | |
| 84 | 106 | 10 | 104 | |
| 85 | 106 | 8 | 104 | |
| 86 | 103 | 6 | 102 | |
| 87 | 109 | 13 | 104 | |
| 88 | | 11 | 105 | |
| 89 | | 14 | 106 | 5 |
| 90 | | 12 | 108 | 1 |

| No. | Loss of 200 grs. in 3 1-2 hours. | Gain at night. | Loss in 2 1-2 hours. | Additional Loss in 4 hours. |
|---|---|---|---|---|
| 91 | 108 | 18 | 109 | 3 |
| 92 | 100 | 8 | 105 | 5 |
| 93 | 102 | 12 | 108 | 5 |
| 94 | 100 | 4 | 103 | 3 |
| 95 | 104 | 7 | 103 | 1 |
| 96 | 103 | | 102 | 1 |
| 97 | 102 | 11 | 110 | 2 |
| 98 | 103 | 12 | 109 | 3 |
| 99 | 102 | 12 | 109 | 3 |
| 100 | 101 | 11 | 106 | 5 |
| 101 | 103 | 10 | 110 | |
| 102 | 101 | 8 | 108 | |
| 103 | 101 | 9 | 110 | |
| 104 | 102 | 10 | 105 | |
| 105 | 102 | 8 | 109 | |
| 106 | 101 | 6 | 109 | |
| 107 | 102 | 9 | 110 | |
| 108 | 101 | 10 | 108 | |
| 109 | 103 | 10 | 105 | |
| 110 | 104 | 10 | 105 | |
| 111 | 101 | 4 | 98 | 9 |
| 112 | 102 | 8 | 101 | 9 |
| 113 | 100 | 3 | 100 | 6 |
| 114 | 101 | 5 | 105 | 1 |
| 115 | 102 | 4 | 99 | 6 |
| 116 | 101 | 3 | 100 | 14 |
| 117 | | | 102 | 4 |
| 118 | 100 | 0 | 99 | |
| 119 | 102 | 4 | 100 | |
| 120 | 102 | 3 | 101 | |
| 121 | 103 | 2 | 100 | |
| 122 | 103 | 2 | 102 | |
| 123 | | | 104 | 8 |
| 124 | 106 | 13 | 104 | 8 |
| 125 | 101 | 1 | 100 | 0 |
| 126 | | | 92 | 3 |
| 127 | 102 | 8 | 105 | 3 |
| 128 | | | 107 | 1 |
| 129 | 103 | 9 | 106 | 2 |
| 130 | 103 | 9 | 104 | 2 |
| 139 | | | 107 | 3 |
| 143 | | | 102 | 4 |
| 146 | 94 | 2 | 107 | 5 |
| 148 | 86 | 3 | 89 | 26 |

All the numbers in the above table over 125, belong to specimens of clay, muck sand, or marl; all of which will be described in other parts of my Re-

port. The results exhibit nothing of importance on which to remark, except perhaps that the specimen of marl (No. 148) appears to possess the strongest retaining power of all the substances tried: and this fact may suggest to us one of the causes that render marls valuable upon land. It will be seen, in the second column, that though only 100 grains of water were added, more than that quantity was usually given off in the course of 3 1-2 hours. This fact led me to expose the soils only 2 1-2 hours the next day; yet even then, more than, 100 grains were usually given off, because of the quantity of moisture absorbed during the night. At the third trial, whose results are given in the last column, I determined not to add any water, and to expose the plates a longer time, and since the last portions of water are always driven off with the most difficulty, I suspect that this last column exhibits better than the others, the relative power of the different soils to retain water in time of drought. I regret, therefore, that an accident has prevented this column from being complete.

### *Power of Soils to absorb Oxygen from the Atmosphere.*

In the excellent paper by Prof. Schubler on the Physical Properties of Soils, referred to on page 55, I find numerous experiments and remarks, not only upon the power of soils to absorb and retain water, but also oxygen gas and heat; as well as their electrical and other relations of importance. But I have room to notice only a few of the new and interesting views which he has presented. *See Journal of the English Agricultural Society, Vol 1 p.* 177. *Lond.* 1839.

Humboldt first pointed out the power of soils to absorb oxygen from the atmosphere: but his views were contradicted: yet they seem now fully established by Schubler. The following Table shows the amount of oxygen absorbed in 30 days, from fifteen cubic inches of air, by 1000 grains of the different soils named. In a dry state they absorbed none.

| | | | |
|---|---|---|---|
| Siliceous Sand, | 1.6 | 0.24 | 0.10 |
| Calcareous Sand, | 5.6 | 0.84 | 0.35 |
| Gypsum Powder, | 2.7 | 0.40 | 0.17 |
| Sandy Clay, | 9.3 | 1.39 | 0.59 |
| Loamy Clay, | 11.0 | 1.65 | 0.70 |
| Stiff Clay or Brick Earth, | 13.6 | 2.04 | 0.86 |
| Grey pure Clay, | 15.3 | 2.29 | 0.97 |
| Fine Lime, | 10.8 | 1.92 | 0.69 |
| Magnesia, | 17.0 | 2.66 | 1.08 |
| Humus, (Geine,) | 20.3 | 3.04 | 1.29 |
| Garden Mould, | 18.0 | 2.60 | 1.10 |
| Arable Soil, | 16.2 | 2.43 | 1.03 |
| Slaty Marl. | 11.0 | 1.65 | 0.70 |

It appears from this Table, that Humus or Geine, absorbs more oxygen than any other soil: And Prof. Schubler says, that it enters into chemical combination with the geine, giving it a higher degree of oxygenation; and that some carbonic acid also is produced. Whereas no chemical union is formed between the other soils and the oxygen absorbed. Here then, we see another mode in which that wonderful substance, geine, acts as a fertilizer; viz. by furnishing carbonic acid and oxygen.

### *Galvanic and Electrical Relations of the Soils.*

According to the same writer, the pure earths, such as sand, lime, magnesia and gypsum, when dry are non-conductors of electricity: but the clays and compound clayey earths are imperfect conductors. All the earths, when oblong dry pieces of them are scraped with a knife, develope negative electricity.

When solutions of Humus—that is, the salts of geine—are exposed to a current of galvanic electricity, decomposition immediately results. The geine collects around the positive pole, while the earths, or alkalies, collect around the negative pole. Do not these facts tend to confirm the views of Dr. Dana respecting the mode in which geine is taken up by the roots of plants; viz. by their forming galvanic combinations with the salts and earths in the soil, whereby the geine and the oxides are decomposed? Do they not, also, strengthen his opinion that geine is a distinct substance, which acts the part of an acid? If it be not a definite chemical compound, how could it be separated and go to the positive pole, by galvanism?

This paper of Prof. Schubler is certainly an important contribution to Agricultural Chemistry; and I regret that it did not fall under my notice, or rather, that it had not been published, when I was prosecuting experiments upon the soils of Massachusetts.

### *Specific Gravities.*

The last column in the general Table, contains the specific gravities of a large part of the soils; that is, their weight as compared with distilled water. In general it will be seen that the most sandy soils are the heaviest; those containing the most geine, the lightest. In the absence of a better method, this character might be employed to determine the amount of organic matter in a soil. But to obtain the specific gravities of soils, cannot be regarded as a matter of much importance; though the results may be of value in the researches of the chemist.

### *Theoretical Characteristics of the different geological varieties of Soils.*

Knowing what simple minerals constitute the different rocks, and what is the composition of those minerals, we can predict what ingredients will exist, and what ones will predominate, in the soils derived from those rocks. Where a soil is derived from quartz rock, or siliceous sandstone, we should expect that silica would greatly predominate, but where argillaceous slate forms the foundation of the soil, alumina will abound. We should expect a large proportion of lime in soils underlaid by limestone: though from causes already explained, analysis does not always verify this anticipation. In soils derived from granite, gneiss, mica slate and those sandstones abounding in fragments of feldspar and mica, we might expect to find potassa, or its salts, because this substance abounds in those minerals. In porphyry soils, for the same reason, soda might be expected: also magnesia in talcose slate soils:

and the single analysis of such a soil by fusion, given on a previous page, corresponds to this prediction. Since iron abounds in all the rocks, we should not expect beforehand to find it peculiarly abundant in any variety of soil.

As to the existence or predominance of silica, alumina, iron, lime and magnesia, in a soil, analysis, as already pointed out, will enable us to determine this point; and, indeed, in respect to most of these ingredients, mere inspection is sufficient for all practical purposes: and from the tables of analyses that have been given, these characteristics, as they exist in the soils of Massachusetts, can easily be determined. But in respect to the alkalies, potassa and soda, which unquestionably exert an important influence upon vegetation where they exist, the case is quite different. As these exist in the feldspar and mica of soils, they are perfectly insoluble in water, but when set free by decomposition, even though converted into salts, they become easily soluble in water: and the consequence is, that rains soon carry them away. We should hence expect the chemist would rarely find them, even in traces. But as some chemists are of opinion that the salts of the alkalies do exist, widely disseminated in soils, I felt desirous of settling the point in relation to the soils of Massachusetts. I selected specimens of nearly every variety of soil in the Government collection, and having boiled 200 or 300 grains for several hours in snow water, until the quantity was rather small, I filtered; and to the solution added a small quantity of a solution of nut-galls. Had there been the minutest quantity of alkali present, the solution would have assumed a greenish tinge: but in no instance was this the case. Hence I infer the absence of alkali, and of alkaline salts. The soils thus tested were Nos. 9, 14, 29, 48, 62, 71, 82, 110, 121, and 124.

From such facts, however, I do not infer the absence of potassa and soda in every form from our soils; but only in a soluble state. On the other hand, it is almost certain, that in many of our soils they must exist in considerable quantity, and I doubt not but they exert an important influence upon cultivation. I impute the productiveness of many of our gneiss, granite, and sienite soils, to these substances. But I am inclined to adopt the opinion of Dr. Dana; who supposes that the rootlets of plants, by means of galvanic agency, have the power to extract alkali from the particles of feldspar and mica in the soil.

If these views are correct, it follows that it can be of little importance for the chemist to determine the precise amount of potassa or soda that may exist in the undecomposed feldspar or mica of a soil. For if the soil have resulted from the disintegration of rock that contains feldspar, he may be sure that alkali is present: But whether it will be of any use:—that is, whether it can be extracted from the soil by the plants, will depend upon the degree of comminution in the soil, and probably upon other circum-

stances not yet fully understood. That such salts as the sulphate of potassa may be found in some peculiar soils, is very probable; and their detection by analysis would be important; but with my present views, I anticipate that the search for them in the soils of New England generally will be in vain.

Such considerations cannot but lead the chemist to enquire, whether other principles, as important as the alkalies, may not exist in soils in such a state that they escape the notice of the analyst; or which he cannot detect in such a state as to afford much aid to practical agriculture. If so, perhaps it may partly explain why careful analysis has accomplished less for agriculture than had been anticipated; and that such is the fact, I am compelled to admit. I do not mean that analysis has been of no service to the farmer. In some instances it has pointed out to him particular substances in his land, that were beneficial or injurious; of which he would otherwise have been ignorant; and in all cases analyses form important materials for improving the theory of agricultural chemistry: which is certainly yet far from perfect. But probably some have been led to suppose, that the chemist, by analyzing their soil, would be able at once to inform them what ingredient might be added to insure fertility. This would imply a degree of perfection in agricultural chemistry to which I think the science cannot yet lay claim. To be sure, the analyst can often suggest the application of ingredients which will probably be beneficial. But the causes on which the growth of plants depends are too complicated, and as yet too imperfectly understood, to permit his recommendations to be infallible. And this leads me to express the opinion, that were a chemist to be employed in making experiments upon the manner in which geine and the salts in soils are taken up by vegetation; as well as upon the best mode of converting soluble into insoluble geine; and to analyze plants in their different stages of growth; very important results might reasonably be expected. The experiments which the farmer makes, that bear upon these points, (and a multitude of such experiments are made every year,) are performed as it were at random, without those fixed principles to guide him, which an accurate knowledge of chemistry would furnish; and hence it is only as it were by chance that any useful results follow.

### *General Conclusions.*

Having as I hope, by the preceding remarks, prevented the indulgence of unreasonable expectations from the examinations which I have made of the soils of Massachusetts, I proceed to state the most important conclusions to which those investigations have conducted me.

First: there is in general too small a supply of calcareous matter in our soils: that is, of lime.

The second great desideratum is an additional supply of geine, or the food of plants.

Hence, thirdly, the great object of the agricultural chemist should be, to discover new supplies of both these substances; and to suggest means for their proper and successful application by the farmer.

These conclusions early forced themselves upon my attention; and all my subsequent researches have served to confirm them. Hence, therefore, I made it my constant endeavor, to discover and examine the character and extent of every deposite that would yield either geine or calcareous matter. I shall now proceed to give the results of my efforts. I shall begin with lime. For although it cannot perhaps be regarded so important as geine, yet in common manures, the farmer possesses a store of the latter, which he knows how to apply. But with the exception of Berkshire County, Massachusetts is very deficient in calcareous matter: and the few spots where it may be found have as yet scarcely begun to excite any attention.

## I. CALCAREOUS MATTER IN MASSACHUSETTS.

### 1. *Marls.*

No form of calcareous matter is so valuable in agriculture as rich marl. This term, however, has been till recently very loosely applied; often meaning nothing more than loose clay, entirely destitute of lime. But all accurate writers now understand it to mean a friable mixture of lime and clay; although the term is extended to beds of calcareous shells that are somewhat hard. Till within a few years, this substance has been neglected in our country; but its remarkable effects in some of our middle and southern states, have awakened the public attention; and it is now sought after with no small avidity. From the nature of our rocks, I had no hope of finding rich marls in any other part of the State, except the County of Berkshire. From that part of the State, many years ago, I had seen a specimen that appeared very rich. I prepared therefore to go in search of the bed from which it was taken; and by the directions of Professor Dewey, I found it in Pittsfield, near the east part of the village, on the borders and in the bottom of a pond covering several acres. It seemed to me very probable that similar beds must occur in other parts of that County where limestone prevails. My search was soon rewarded by the discovery of an extensive bed in the northwest part of Stockbridge on land of Mr. Buck; whose thickness was about

two and a half feet, and probable extent, very great. Also a second bed in the same town, only four miles from the court-house in Lenox. Also a third bed in the northeast part of Lee, at the Mills of Sedgwick and Co., the thickness of which, in some places, is about ten feet; though its extent is but a few acres. Also, several beds in West Stockbridge in various parts of the town. The limited time which I gave to these researches did not allow me to make but slight examinations in other towns. But I have little doubt that similar beds of marl will be found in various other places in the County; especially in Sheffield, Great Barrington, Egremont, Alford, Richmond, Lanesborough, New Ashford, and perhaps in Williamstown, Adams, Cheshire, Dalton, and New Marlborough. I am confirmed in this opinion from the fact that since I visited the County several other beds have been discovered.

A second bed has been found in Pittsfield, about a mile south-east of the village. Also a bed in Stockbridge, a little northeast of the village on the road to Lenox. For specimens from both which places, I am indebted to Professor Dewey. A third bed has been found covering several acres in the north-west part of Lee, near a pond, on land of Messrs. Lemuel and Cornelius Bassett. The thickness of the marl, which commences about a foot below the surface, is in some places from four to seven feet, and in others, from ten to twelve feet; and from 200 to 300 loads have been taken from it by the Messrs. Bassett. Specimens from all the beds that have been described will be found in the collection accompanying this Report. (See Nos. 148, 149, 150, 151, 152, 153, 172, 173, 174, 175.) I am informed also, that a small bed exists in Tyringham, and another in Sheffield, and two at least occur in Great Barrington.

The purest of these marls when dry, are almost as white as chalk, and much lighter than common soil, as may be seen from the specific gravities of a part of them in the table of their analysis below. When wet they are of a light gray color, especially if they contain much organic and earthy matter: indeed the degree of their whiteness is no bad index of the quantity of lime that they contain. When wet they are quite plastic and adhesive: when dry, they fall into a fine powder. Hence they are in a most favorable state for being spread upon land. They are found almost exclusively in swampy ground, generally in quite wet swamps, and are always covered by a stratum, often several feet thick, of black vegetable matter approaching to peat. Hence, as these swamps are rarely excavated, the marl is not apt to be discovered; or if found, it is supposed to be nothing more than white clay and sand, which, indeed, it does very much resemble. In order to ascertain the presence of marl in a swamp, I prepared an iron rod, several feet long, near the end of which was a grove, in fact it formed a sort of auger. When pressed into the ground and withdrawn, it would always retain in the groove

some of the matter from the bottom of the hole, and in this way, in a few minutes, not only the existence of marl might be ascertained, but the thickness of the bed. Yet after all, since the swamps where it occurs are usually very wet, and easily penetrated, a rough pole is better for discovering marl and its thickness, than the iron borer which I have described. For some of it will adhere to a pole plunged into it, even though that pole must be drawn through several feet of vegetable mud above it. And if the pole be plunged to the bottom of the bed, the distance along the pole covered with marl, will show the thickness of the bed; except that the lower extremity of the pole will show beneath the layer of marl the clay or sand as far as they were penetrated: and this extent must be subtracted from the whole length covered with marl. I have been thus particular in describing the method of searching for marls, in the confidence that if gentlemen residing in the towns above mentioned will adopt it, many new beds will be brought to light.

There is a substance in the central and eastern parts of the State, in exactly the same situation as the marl of Berkshire, which resembles it also very precisely in external characters, and is also like marl very light; and yet it is not marl. It does not contain carbonate of lime, but is composed chiefly of silica. Specimens of it will be found in the collection from several places. (See No. 157, which is from Spencer; No. 169, from Barre, and No. 170, from Andover.) It is easy, notwithstanding its general resemblance, to distinguish it from marl by a few drops of vinegar, oil of vitriol, aqua fortis, or any other acid. If a substance be marl, the acid will produce in it small bubbles occasioned by the escape of gas—if not marl, no effervescence will be produced. And this is a universal test, which is almost infallible, for distinguishing marl in all circumstances.

One other circumstance respecting the Berkshire marl, which will aid in distinguishing it. It abounds every where with small fresh water shells, such as now occur in the ponds of that region, and therefore it is unquestionably true fresh water marl, usually called shell marl. The epidermis of the shell is usually gone. Such shells are rarely found in much quantity where lime does not exist, although I have seen them in mud that did not effervesce. But their presence should lead us to search carefully for calcareous matter: for how can these animals form their shells without lime?

The Berkshire marls, above described, appear to me to be some of the richest and best that ever occur. Marls are usually valued only for the calcareous matter which they contain. But by adopting Dr. Dana's method of analysis, we find that they also contain no small quantity of soluble and insoluble geine, derived from the vegetable matter that covers them. This must make them still more valuable when applied to the soil. They contain likewise a small portion of phosphate of lime, increasing their value still

more: while the silicates in them, the only part that is of no value, are in most cases extremely small. The following are the results of the analysis of the specimens in the Government collection.

I have added the analysis of a specimen of similar marl from Farmington in Connecticut, for which I am indebted to Professor Silliman. For the geological character of Farmington and the surrounding region is very much like that of Springfield and West Springfield; and therefore I cannot but hope that some of the swamps in the latter places may contain it. The bed in Farmington is said to be extensive.

Marl of this description is usually supposed to result wholly from the decomposition of minute fresh water shells: But since it is not unusual for water in limestone to contain a small quantity of carbonate of lime in solution, by means of free carbonic acid, it seems to me that the deposition of this carbonate of lime in a pulverulent state, in consequence of the escape of the acid, is the probable origin of a large part of the marl.

| No. | LOCALITY. | Soluble Geine. | Insoluble Geine. | Phosphate of Lime. | Carbonate of Lime. | Carbonate of Magnesia. | Silicates. | Water of Absorption. | Specific Gravity. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|
| 148 | Stockbridge, (Mr. Buck's Farm,) | 4.3 | 4.6 | 0.7 | 73.4 | 0.15 | 13.5 | 3.3 | 1.82 | 2 1-2 feet thick. |
| 151 | do northeast of the village, | 5.0 | 8.9 | 0.6 | 46.0 | trace. | 36.6 | 2.9 | | |
| 203 | do do - - - | 0.6 | 3.8 | 0.8 | 31.8 | | 59.8 | 1.7 | | 1.5 Sulphate of Lime: Specimen from another part of the bed. |
| 149 | Pittsfield, east of the village, | 3.1 | 3.5 | 0.7 | 86.4 | 0.46 | 3.1 | 3.0 | 1.82 | 4 feet thick at least. |
| 152 | do S. W of village (Mr. Strong's lot,) - - - - - | 3.1 | 3.2 | 0.4 | 64.8 | trace. | 25.2 | 1.9 | | |
| 150 | West Stockbridge, Mr. Reed's land,) - - - - | 1.7 | 5.0 | 0.5 | 74.8 | 0.53 | 14.7 | 2.8 | 1.61 | |
| 153 | Lee, Sedgwick & Co's mills,) | 1.2 | 2.1 | 1.0 | 93.2 | no trial | 0.9 | 1.6 | 1.89 | Exposed to the action of running water. |
| 172 | do (L. Basset's bed, near the surface,) - - - | 1.8 | 2.2 | 1.4 | 93.0 | do | 2.2 | 0.4 | | 9 to 12 feet thick. |
| 173 | do do 10 feet below the surface, - - - - | 1.6 | 2.8 | 1.0 | 88.8 | do | 4.4 | 1.4 | 1.75 | |
| 174 | do (C. Bassett's bed,) - - | 2.6 | 3.4 | 1.2 | 86.2 | do | 5.0 | 1.6 | | Nos. 172, 173 and 174 are from the same bed. |
| 175 | do (Sedgwick's mills,) - - | 0.8 | 4.4 | 1.0 | 83.6 | do | 9.2 | 1.0 | | Not Exposed to the action of running water. |
| 204 | Farmington, Ct. - - - | 3.0 | 9.5 | 0.4 | 64.4 | do | 17.8 | 2.9 | | 2.0 Sulphate of lime. No trial for the sulphate in the other specimens. |

The amount of calcareous matter in these marls is unusually large, with the exception of one of the specimens from Pittsfield, and another from the east part of Stockbridge. And these specimens were not taken directly from the beds, but as they had been thrown out in making excavations; and the marl was obviously mixed with loam and sand; so that the quantity of carbonate of lime by the analysis is doubtless too small.

Again, most marls are only in part pulverulent, or easily crumbled down, and they require a long time after being mixed with the soil, before they will exert a favorable action upon it. But these are all in a state best adapted for immediate use; and when we add to these considerations those already made concerning the other ingredients of these marls, I cannot but feel that Berkshire possesses in them a very great treasure. I doubt not but an inexhaustable supply may be found there, not only for the county but for exportation. And since the most numerous beds yet discovered occur very near the point (West Stockbridge) where two great rail roads are soon to intersect, I cannot doubt that this marl will be among the articles of export at least a considerable distance. The marls of New Jersey and Virginia, it is well known, are already beginning to be transported a great distance. And if any marls are rich enough to be thus conveyed by land or water, surely those of Berkshire must be of the number. It will doubtless require a long time to satisfy many of our farmers of the value of marl: and especially as we may expect many failures from applying this marl in improper quantity, or in the neglect of collateral circumstances essential to success. But unless a vast amount of experience in the use of marl in Europe and in this country is to be set aside as a ground of judgment, these marls must sooner or later work an important improvement in a portion of the agriculture of this State.

There is an important fact derived from the analysis of soils that have been given, relative to the character of those in Berkshire county. It had formerly been supposed, that the soils of that county contain so much lime that marls would be of no service there. But it appears that they contain scarcely any more of this substance, either in the form of carbonate, sulphate, or phosphate, than the other soils of the state. At least, the specimens analyzed do not; and these were taken at random from fields underlaid by limestone; so that probably they show about the average quantity of lime in the soils of the county; though I doubt not that soils may be found there containing more of this substance. I think this may be a safe rule to follow by the farmers of that county. If a soil effervesces with vinegar, or other acids, they may infer that marl will be of little service. If it do not effervesce, they may safely apply marl. And judged of by this rule, I doubt not that four out of five of the Berkshire soils will be found to need it. It ought to be expected, however, that this rule will sometimes fail; because a soil may contain lime in some other form than the carbonates, so that for several years the marl may do no good.

### *In what Quantity and Mode shall Marl be applied?*

I do not conceive that it falls within the sphere of duties assigned me by the government, to go into details respecting the mode and the quantity in which marl shall be applied, except so far as these questions can be answered by agricultural chemistry. It is well known that, in many instances, lands have been injured by over marling; and hence one is met everywhere with the questions above suggested. And certain it is, that no general rules have thus far been followed or proposed. Nor can we get any general rules on the subject until the manner in which lime acts upon soils and vegetation is understood. Here, it must be confessed, great confusion and a variety of opinions have prevailed. The action of lime is undoubtedly quite complex, and considerably different on different soils; which renders any general theory more difficult. The doctrines respecting geine, which have been explained, appear to throw more light on this subject than has ever before shone upon it; though some points still remain obscure; and as Dr. Dana has obligingly furnished me with his views on the subject, I shall present them without hazarding any opinion of my own; except to say, that his theory is manifestly in advance of any that has hitherto appeared.

### *Theory of the action of Lime on Soils, Manure, and Vegetation.*

"The action of lime is threefold; each distinct. 1. It is a *Neutralizer:* 2 a *Decomposer:* 3. a *Converter*. 1. I have already alluded to some acid soils: free phosphoric acid, geic, acetic, and malic acids, also occasionally exist in a free state in soils. Here lime acts as a neutralizer.

2. Soils may contain abundant geates; particularly geate of alumina, the least of all demanded by plants. Long formed and sun-baked, they are scarcely acted on by rain or dew, and are almost useless. Here lime, by decomposing these metallic and earthy geates, forms a combination, which, in its nascent state, is readily dissolved. If the carbonate of lime acts better than the hydrate, it is because, following a well known law, double decomposition is easier than single. If any acid geine exists in the soil, or any free acids, carbonic acid is then liberated; it acts on the geate of lime, supergeates result, and these are easily soluble."

"3. The great use of lime is as a *converter*; turning solid and insoluble geine, nay, I go further, solid vegetable fibre, into soluble vegetable food. Here is the great puzzle, the point where our philosophy seems to leave us: giving us our choice, to refer this action to one of the numerous cases of mysterious '*catalytic*' change, with which we are becoming every day more and more familiar, or to explain the process by referring the whole to *saponification*. I use this word as conveying to you at once what I mean;—but I do not mean to say that the product of lime and vegetable matter is soap; but I cannot make myself more intelligible to a farmer than by saying, this lime makes compounds of vegetable matter, just as it makes soapy compounds of oil and fat. The action of lime on geine I take to be of the same nature, as its action on oils and fat. It is well established that animal and vegetable oils and fats are converted into acids by the action of alkalies, earths, oxides, and even by vegetable fibre itself. The general law is, that whenever a substance, capable of uniting with the acid of fat or oil, is placed in contact with fat or oil, it determines the production of acid. Now we have seen that alkali produces a similar change on geine; it developes acid properties. I go further, if alkali has converted vegetable oil and geine into acids, I see no reason why a similar action may not be produced by all those substances which act thus on oil. Hence *lime*, earths, and metallic oxides, convert geine into acid: as fast as this takes place, so fast it becomes soluble. Then too the long action of air on insoluble geine, rendering it soluble, is it not analogous

to the action of air on oils. Both evolve in this case, vast volumes of carbonic acid, the oil becomes gelatinous and soluble in alkali; does not a similar change occur in geine? It is possible that during the action of lime on geine, a soluble substance may be produced, bearing the same relation to this process that glycerine does to saponification. These views you will see need to be followed out experimentally. If found tenable, the most signal benefit will result. We place manures on a new foundation, on which great practical results may be erected."

### *Practical application of the Theory of the action of Lime.*

Taking the preceeding principles by Dr. Dana as our guide, we may lay down a few general rules for the application of marls.

1. Enough ought to be applied to neutralize all the free acids in a soil; which may be known by its ceasing to produce acid plants, such as sorrel and pine. Generally, however, the amount required for this purpose is small.

2. It will be serviceable to add enough to convert the earthy geates of a soil into geate of lime. The richer a soil is, the greater we may conclude is the quantity of geates which it contains.

3. It will be serviceable to add enough to convert all the insoluble geine and vegetable fibre in a soil into soluble geine. Hence the richer a soil is, and the more manure is added, the more marl will it bear with benefit. Indeed, *there appears to be no danger of adding too much marl, provided a sufficient quantity of manure be also added.* Ignorance of this principle, I apprehend, is the source of most of the failures that have occured in the use of lime upon soils. Farmers have supposed that its action was like that of common manure, viz., to serve as direct nourishment to the plant; whereas it only *cooks the food*, if I may be allowed the expression, which exists in the soil, or is added along with the lime. In nearly all cases of over marling which I have read of, a fresh supply of manure has been found to be the remedy; which shows the truth of the above principle. Agriculturalists have spread marl alone, or with very little manure, upon land that has been worn out, that is, whose geine has been exhausted; and because such soils have not thereby been recruited, they have inferred that lime was injurious. Without acids, or geine, or geates, or vegetable fibre, to act upon, much excess of lime appears to operate injuriously, so as to diminish, instead of increasing the crop. They have also expected a sudden and surprising increase of fertility: whereas in some cases the chief benefit seems to consist in causing the land to produce for a greater number of years, by preventing the ultimate decomposition and escape of the organic matter. In general, however, it will add also to the yearly product: but those who employ marl or lime in any form, ought to moderate their expectations, that they may not be disappointed, and to be satisfied if they can slowly and surely improve their

**lands as they most assuredly can do, by this substance, provided they do not expect to accomplish it by the use of lime alone.**

These general rules can afford only a general guidance as to the quantity of marl proper to be used. Both marls and soils vary so much in their composition, that probably direct experiments will always be necessary to ascertain the quantity of any new variety of marl that will be most serviceable. And should any be disposed, as I doubt not they will be, to try the marls above described, I beg leave to recommend to them, as the best practical treatise that has been published in this country, on this subject, " An Essay on Calcareous Manures," by Edward Ruffin, Esq. of Virginia, Shellbanks, 1835. This gentleman has tried a vast number of experiments on the subject, and the perusal of his work is almost indispensable to any one who would successfully prosecute it. He says, "if the nature of the soil, its condition and treatment, and the strength of the marl were all known, it would be easy to direct the amount of a suitable dressing: but without knowing these circumstances, it would be safest to give 250 or 300 bushels to the acre of worn acid soils, and at least twice as much to newly cleared, or well manured land." (Essay pp. 54.)

As to the best mode of applying marl, theory would lead us in general to prefer the method usually adopted, viz: to mix it with compost before spreading it on the soil. And I would here express a hope, that if experiments are made on the Berkshire marls, a portion of the black vegetable matter that lies above them, may sometimes be mixed with them, to see whether it may not become converted into a geate, and thus increase the value of the marl. It would indeed be an important discovery, if from the same swamp both the geine and the lime could be obtained, in a state proper to sustain vegetation.

In a few instances the Berkshire marl has been tried upon cultivated land. In the North part of Stockbridge, several years ago, Mr. Hadsel Buck spread 40 loads from the bed on his farm upon a field of grass, and he describes the effect as excellent. A mile or two east of this spot Capt. Enos Smith, many years ago, took a quantity from another bed and spread it upon grass ground with very marked benefit. It has also been tried in Pittsfield, by Samuel A. Danforth, Esq with encouraging success.*

The agricultural surveyor of Massachusetts, in his Second annual report, has mentioned a few recent trials with these marls that have not proved so successful. In one instance, that in Sheffield, it was spread alone upon a wheat field, and no apparent effect was produced. I should not expect any effect from such an experiment, especially the first year: for probably this mode of applying it is one of the poorest: and secondly, in Europe "it is well known that lime produces scarcely any sensible effect as a mauure at the beginning. Even the first year after it is applied to the soil its effects are inconsiderable, in comparison of what it produces in the second and succeeding years" (*Morton on Soils p.* 177) And finally for aught that appears, the soil may already contain all the lime immediately necessary: for it is based upon limestone. In the other case, a shovel full of marl was put into each hill of potatoes, and although the crop appeared better early in the season, it was not so superior at the time of harvest. In this case the quantity of marl used was much too large; according to any rules that I have ever seen laid down.

Now in my report of 1838 I predicted such results as these: and I shall expect more of them before the best mode of applying the Berkshire marl shall be discovered. Nor would it be

* I feel under great obligations to Hon. Judge Walker, and H. W. Bishop, Esq. of Lenox, for their attention and assistance in searching for beds of marl in that vicinity. Also to Charles B. Boynton, Esq. of West Stockbridge. To Sedgwick & Co. and Mr. Lemuel Basset, I am indebted for the specimens from their marl beds in the government collection. I might name several other gentlemen in that county who have given me much assistance.

strange if many should hence become entirely sceptical as to the value of this substance, and give up further experiments with it. But how unphilosophical to set a few unsuccessful but imperfect experiments, continued only a year or two, against thousands of successful experiments made in Europe and in our own country for a great number of years! I am not, however, commissioned to try experiments with these marls, but to point them out to others. And I pledge myself, that they are precisely of the same nature, and as rich in calcareous matter, as those which in other parts of the world have produced most valuable effects upon agriculture. And I have little doubt, but if the present generation do not derive similar benefit from them, posterity will.

I have supposed that the discovery of earthy substances containing a much less quantity of calcareous matter than the marl that has just been described, might be of great benefit to agriculture in a region so destitute of lime as Massachusetts in general. Accordingly, I have examined our clays and diluvial deposites with reference to this point and shall now give the result of my researches.

## 2. *Marly Clay.*

The clays of Massachusetts are in general destitute of carbonate of lime, except that they sometimes contain remarkable concretions called *clay stones*, which usually consist of about 50 per cent. of this substance. In a few instances, however, I have discovered beds that contain a few per cent. of carbonate of lime; not enough to bring them under the denomination of marl; yet in sufficient quantity to make them objects of interest in agriculture. For as will be shown in another place, clay alone often exerts a very favorable influence upon land; much more probably, when it is united with calcareous matter. The following table exhibits the composition of all the beds of marly clay which I have discovered; analyzed by fusion with carbonate of soda in the usual way: after extracting the carbonate of lime by an acid.

| No. | Locality. | Silica. | Alumina. | Protoxide of Iron. | Carbonate of Lime. | Lime. | Magnesia. | Water of Absorption. | Loss. |
|---|---|---|---|---|---|---|---|---|---|
| 146 | Williamstown | 60.24 | 15.53 | 7.57 | 11.7 | 0.12 | 1.86 | 2.3 | 0.68 |
| 147 | North Adams, | 59.07 | 5.49 | 4.28 | 28.0 | trace | 1.59 | 0.7 | 0.87 |
| 219 | South Lee, | 51.79 | 21.47 | 7.89 | 12.2 | do | 2.02 | 2.8 | 1.83 |
| 206 | Springfield, | 64.81 | 14.40 | 5.30 | 7.6 | do | 2.36 | 3.8 | 1.73 |

The specimen from North Adams, where it occurs a little east of the village, in an excavation for making brick, ought rather to be called calcareous sand, than marly clay: as will be obvious by inspecting it.—That from Springfield was obtained in boring beneath Connecticut river under the direction of Major Whistler, the engineer on the Western Rail Road: to whom, and to Capt. Swift, I am indebted for specimens and a Section which will be more fully described in the scientific part of my report. The

clay on the banks of the river, so far as I have examined, does not effervesce: yet this point, which is one of great importance, needs farther examination. The specimen from South Lee was obtained from a clay bed on land of Mr. Merrill, a mile and a half east of the village, on the Housatonic river. Research, I have no doubt, will bring to light other beds, especially in Berkshire county: and I should not think it strange if this substance should prove more immediately beneficial upon the soil, than the rich marls that have been described.

### 3. *Peculiar Calcareous Soil.*

In passing from South Lee to Stockbridge, a very peculiar limestone rock may be seen, although from its dark color it is not usually supposed to be limestone. It is indeed very impure, and will never be used either for burning into quicklime or for marble. Yet by decomposition it produces a peculiar reddish soil, which appears not only to be very fertile, but I apprehend may be employed advantageously to spread upon other soils. My attention was drawn to it, by the fact that it has been so employed to some extent upon gardens in Stockbridge. And as this rock may probably be found more or less abundantly, nearly all the way from Stockbridge to the north line of the state, I thought the soil resulting from it deserved an analysis. The specimen made use of, (No. 139,) was obtained near a ledge of this limestone, a little east of the village of Stockbridge, and yielded the following results.

| | |
|---|---|
| Water of Absorption, | 3.80 |
| Soluble Geine, | 0.93 |
| Insoluble Geine, | 1.99 |
| Carbonate of Lime, | 30.57 |
| Sulphate of lime, | 1.40 |
| Phosphate of Lime, | 1.63 |
| Lime, | 0.09 |
| Silica, | 46.43 |
| Alumina | 6.82 |
| Peroxide of Iron, | 4.01 |
| Magnesia, | 1.03 |
| Loss, | 1.30 |
| | 100.00 |

A glance at the preceding analysis lets us at once into the secret of the fertilizing properties of this peculiar soil. For to say nothing of the geine, whose quantity is small, the salts of lime, which it contains, must make it valuble as a manure. And as to the iron, I am inclined to believe that it exists in the rock originally as a carbonate: though I have not ascertained this experimentally. But if such be the case, the carbonic acid which escapes, as the oxide of iron is evolved, will probably be seized by the organs

of growing plants. Does not this substance demand the attention of Berkshire farmers? If it can be found of the character of that analyzed in considerable quantity, it can hardly fail of being a valuable means of improving much of their land.

In addition to the good effects of this calcareous substance upon soil, which I have mentioned, as shown in Stockbridge, I would refer to a district in Adams, where the soil is highly impregnated with it. The eastern part of Saddle Mountain has a valley running nearly north and south, and rising very high at its southern extremity, called the Tunnel. I was surprized to find in this valley some of the best dairy farms in the county; and even at its southern extremity, which cannot be less than 1200 feet above the villages in Adams, the luxuriance of the grass I have hardly seen excelled any where in the state. On examining the soil, I found it to be highly charged with the peculiar compound under consideration, derived from the bastard limestone which runs through the valley, and whose gradual decomposition not unlikely may have formed the valley. An analysis of this soil is given on a preceding page: (No. 192, p. 42.) from which it seems that the carbonate of lime is almost exhausted, and that it possesses no other remarkable characters. But in the facts above developed, I doubt not we have the secret of its unusual fertility.

### 4. *Calcareous Diluvium.*

In the red sandstone of the valley of Connecticut river, beds of fetid limestone occasionally occur: and besides, in the towns of Springfield, West Springfield, and South Hadley, the red slaty rock contains a few per cent. of carbonate of lime. In early times this rock has been extensively worn away, and the small fragments and fine sand or clay, thence resulting, have been piled up over the greater part of those towns. This accumulation of detrital matter, I call *diluvium;* and on applying acids to it, in very many places in the towns above named, I found it strongly to effervesce, especially when dug from a little depth. The lime serves as a cement, so that in most places it is almost as hard as a solid rock, and requires a good deal of labor to get it up. But exposed to wet, heat, and cold, it at length crumbles down, and becomes fit to spread upon land; although the size of the pebbles often might injure grass fields, unless they were separated by means of a riddle. Since this diluvium was deposited, a thick layer, first of clay, and above this, of sand, has been brought over most of the region, so that the diluvium appears only in those places where the sand and clay have been worn away. But it occurs so often that it is accessible in a multitude of places. I will mention the banks of Agawam river, a little west, and also south, of the village of West Spring-

field; also at the south end of the village of Springfield, in several places along the banks of the small river on which stand the lower "Water Shops." In one spot on the north bank, is an elevation belonging to the United States' Government, which ten years ago was nothing, but a barren sand hill. A large quantity of this diluvium, and of the disintegrating slaty rock beneath it, was carted upon this spot, and not only has it fixed the sand, but produced a coating of clover, grass, and young locust bushes. I was there informed, that near the same spot, six or eight years ago, some of this diluvium was put upon a small sandy ploughed field, and that the good effects are still visible. In another case eight years ago, some of it was mixed with a small quantity of hog manure, and the land still produces better crops. The testimony here, and also at Chicopee Factory Village, as well as in West Springfield, was, that wherever this diluvium is spread, clover soon makes its appearance; a result almost uniformly attending the judicious application of marl.

In the banks of Chicopee river, in numerous places from its mouth nearly to Putt's Bridge, thick deposites of this diluvium appear. An enormous bed of it exists on the east bank of Connecticut river, a little south of the village at South Hadley Canal. It occurs, also, in abundance, a little south of the village of South Hadley. I have searched in vain for it in other parts of the valley of the Connecticut. No where else in Massachusetts does the red sandstone appear to contain enough of carbonate of lime to make its detritus sensibly calcareous. And although I have been told, on good authority, that in the vicinity of Hartford and Middletown, Ct., the diluvium does effervesce with acids, yet after repeated trials in various places from Massachusetts to Middletown, I have not found any that was sensibly calcareous. At present, therefore, I must consider this variety confined to the three towns above named: though I doubt not that I might safely add Longmeadow and Wilbraham. I have analysed only three specimens; but these probably will give us about the average amount of carbonate of lime. The specimens analyzed will be found in the state collection.

| No. | Carbonate of Lime. | Silica and Alumina. | Carbonate of Magnesia. | Peroxide of Iron. | Water of Absorption. | Locality. |
|---|---|---|---|---|---|---|
| 154 | 6.3 | 80.0 | slight precip. | 12.4 | 2.3 | Chicopee Factory, Springfield. |
| 155 | 4.8 | 83.2 | slight precip. | 11.0 | 1.0 | Springfield, Lower Water Shops. |
| 156 | 8.0 | 71.6 | 0.4 | 19.0 | 1.0 | West Springfield. |

The amount of calcareous matter in this diluvium appears small, when compared with that in the Berkshire marls. And I presume it will not be found valuable enough as a manure to be transported a great distance. But

it ought to be recollected, that it needs only a small quantity of lime in a soil to work wonders upon vegetation. And further, it happens that in the immediate vicinity of nearly every bed of this substance, is a great deal of that sterile sandy land, which most needs a coating of marly clay, which is in fact the character of the calcareous diluvium. The large quantity of peroxide of iron which it contains, will probably also be useful on such a soil. And where this substance can be carted directly upon such fields, I cannot doubt, but they might be made permanently fertile without great expense. I trust that some of the farmers in the vicinity of this diluvium, will at least be tempted to try a few square rods of sandy land in this manner; and then they can judge whether its more extensive application may not be profitable. Who knows, but this substance, which has hitherto been regarded as a sign of utter barrenness, and employed only for mending roads, may at some future day spread fertility over many a field now scarcely worth cultivation!

I ought to remark, that in many places, beds of this diluvium occur which contain little or no calcareous matter, because the rocks from which they were derived, contain none. Hence in using this substance upon soils, none ought to be employed which does not effervesce with vinegar, or other acids. By omitting this precaution, an experiment may fail, which would otherwise succeed.

### 5. *Limestone.*

Upon the whole no rock is so important in an economical point of view as limestone; and no part of the world is better supplied with this material than the western part of Massachusetts. Enough exists to furnish the whole state, and I might say probably with truth, the whole of New England, through all future generations with marble and quicklime, were it spread through the country. But in other parts of the state limestone is comparatively rare; and I have searched for it with more diligence than for almost any other substance. The numerous small beds which I have discovered, lead me to hope that I have not labored altogether in vain. I shall now present a table of the analysis of nearly every deposite which I have found out of Berkshire county; and of several of the most important localities in that county. The more common limestones there I have neglected; because they will never probably be used. But inferior varieties will be valuable in other parts of the state; and therefore, I have analyzed all which I have discovered.

I have reduced all the following analyses to a centesimal standard: and although there was always a small loss in the process, I have neglected it; because in a practical point of view it can be of no importance, and would somewhat embarrass any one not conversant with chemical processes, who wishes at a glance to determine the composition of our limestones.

The numbers in the first column refer to those in the State Collection. I have added also a column of specific gravities; although this item can be of no great importance.

I am inclined to believe that in most of the limestones of Massachusetts, the iron exists in the state of a carbonate: And such a supposition accords rather better with my analyses than to suppose it in the state of peroxide. But as the quantity of iron is in most cases very small, and the difference as to amount between the carbonate and peroxide is slight, it is not easy to determine whether a loss so small as that difference is to be imputed to errors of analysis, or to the escape of carbonic acid: and as in the analytical process the iron must be estimated in the state of peroxide, I have put it down in the table as such. If any one wishes to reduce this to the state of carbonate, he can do it by this formula; 978: 878:: Peroxide: Protoxide. Then 61.44: 100:: Protoxide: Protocarbonate. Or Protocarbonate $\div$ 1.46 = Peroxide.

| No. | LOCALITY. | Carbonate of Lime. | Carbonate of Magnesia. | Peroxide of Iron. | Silica, Alumina, &c. | Specific Gravity. | Per cent. of Quick lime. |
|---|---|---|---|---|---|---|---|
| 429 | North Adams, crystalline, white, | 99.60 | | trace. | 0.40 | 2.74 | 55.78 |
| 432 | Lanesborough, do do | 99.40 | | do | 0.60 | 2.69 | 55.66 |
| 1901 | West Stockbridge, do do Fitch's Quarry, | 98.10 | 1.16 | 0.14 | 0.60 | 2.67 | 54.94 |
| 1903 | do Boynton's Quarry, do do | 98.67 | 0.47 | 0.08 | 0.78 | 2.71 | 55.25 |
| 1905 | Lanesboro' best for marble, do | 96.11 | 2.28 | 0.22 | 1.39 | 2.74 | 53.82 |
| 1908 | Boston Corner, white crystalline, | 87.32 | 1.20 | 0.23 | 11.25 | 2.69 | 48.90 |
| 1916 | Hancock greyish, do | 93.38 | 3.56 | 0.57 | 2.49 | 2.67 | 52.29 |
| 2497 | Worthington, white, do | 99.85 | | 0.15 | | | 55.92 |
| 470 | Bernardston, do do | 98.38 | | 0.62 | 1.00 | 2.72 | 55.09 |
| 459 | Whately, grey, do | 66.00 | | | 34.00 | 2.72 | 36.97 |
| 1919 | do 2d Specimen, do | 64.66 | 5.01 | 1.54 | 28.79 | | 36.21 |
| 463 | Southampton, grey, do | 38.40 | | | 61.60 | 2.93 | 21.50 |
| 494 | Walpole, do do | 70.30 | | | 29.70 | 2.80 | 39.37 |
| 1910 | Attleborough, do compact, | 94.60 | | | 5.40 | 2.71 | 52.98 |
| 2503 | Norwich, do micaceous, | 53.80 | | | 46.20 | 2.79 | 30.13 |
| 1907 | Sheffield, white crystalline, Girard College Quarry, | 97.80 | | | 2.20 | 2.75 | 54.77 |
| 1906 | Egremont, white, crystalline, | 92.80 | 1.20 | | 6.00 | 2.69 | 51.97 |
| 436 | Sheffield, dolomitic granular, | 58.04 | 40.40 | | 1.20 | 2.84 | 32.70 |
| 1925 | do do marble, | 54.87 | 40.61 | 0.38 | 4.14 | 2.83 | 30.73 |
| 437 | Lanesborough, Gray Marble, | 93.60 | 5.50 | 0.60 | 0.30 | 2.76 | 52.42 |
| 433 | New Ashford, Flexible marble, | 81.80 | 16.20 | 0.60 | 1.40 | 2.68 | 45.81 |
| 1927 | New Marlborough, Dolomitic, Capt. Smith's Kiln, | 54.24 | 44.28 | 0.59 | 0.89 | 2.81 | 30.37 |
| 1933 | do crystalline, dolomitic, Hadsell's Quarry. | 55.45 | 42.76 | 0.86 | 0.93 | 2.88 | 31.05 |
| 1924 | Tyringham, South Part, Crystalline Magnesian, | 54.34 | 44.24 | 0.67 | 0.75 | 2.77 | 30.43 |
| 1931 | Tyringham, N. W. Part, Magnesian, | 61.88 | 33.56 | 0.46 | 4.10 | 2.82 | 34.65 |
| 1942 | Becket, S. E. Part, Magnesian, | 58.31 | 28.61 | 1.24 | 11.84 | 2.84 | 32.65 |
| 447 | Pittsfield, gray, fine granular, | 54.60 | 43.92 | 0.55 | 0.93 | 2.86 | 30.57 |
| 1935 | Williamstown, foot of Saddle Mt. | 55.79 | 42.96 | 0.47 | 0.78 | 2.79 | 31.14 |
| 448 | do Grey, near the College, | 52.31 | 32.79 | 0.74 | 14.16 | 2.82 | 29.29 |
| 1932 | Great Barrington, clouded Marble, | 60.30 | 38.09 | 0.65 | 0.96 | 2.84 | 33.77 |
| 216 | Compact Limestone, Agawam, | 30.81 | 18.33 | 5.53 | 45.33 | | 17.25 |
| 1758 | do 2d Specimen, | 26.04 | 13.45 | 6.51 | 54.00 | | 14.58 |
| 1759 | Argillaceous Limestone, Agawam, | 55.16 | 22.21 | 7.07 | 15.56 | | 30.89 |
| 1920 | Micaceous do Ashfield, | 46.85 | 1.69 | 1.55 | 50.00 | | 26.24 |
| 1921 | do do do 2d Specimen, | 45.13 | 3.50 | 2.70 | 48.67 | | 25.37 |

| No. | LOCALITY. | Carbonate of Lime. | Carbonate of Magnesia. | Peroxide of Iron. | Silica, Alumina, &c. | Specific Gravity. | Per cent. of Quick-lime, &c. |
|---|---|---|---|---|---|---|---|
| * | Newbury, | 80.72 | 2.97 | 0.72 | 8.00 | | 45.20 |
| 1934 | Lanesboro' East Part, burnt for lime, | 56.82 | 38.50 | 0.67 | 4.01 | 2.81 | 31.82 |
| 1937 | Lee, 1 mile east of village, burnt for lime, | 54.80 | 44.98 | 0.22 | | 2.77 | 32.88 |
| 1938 | Dalton, near the village, | 56.58 | 43.07 | 0.35 | | 2.86 | 31.68 |
| 485 | Bolton, quarry, crystalline, | 61.80 | 27.00 | | 1.20 | 2.80 | 34.61 |
| 491 | Chelmsford Quarry, do | 56.52 | 39.38 | 0.90 | 3.20 | 2.85 | 31.65 |
| 496 | Stoneham, white compact, | 59.28 | 15.71 | 1.21 | 23.80 | 2.84 | 33.19 |
| 211 | W. Springfield gray, fetid. Paine's Quarry, | 93.48 | 0.90 | | 5.60 | 2.73 | 52.35 |
| 1764 | Springfield, Chicopee Compact Septaria, | 46.06 | 27.35 | 5.62 | 20.97 | 2.74 | 25.79 |
| 1757 | do do fetid, gray, | 86.80 | | | 13.20 | 2.73 | 48.61 |
| 1763 | do Cabotville, Septaria, | 43 69 | 39.35 | 3.39 | 13.57 | | 24.47 |
| 1941 | Middlefield, Cole's Brook, white, | 56.25 | 31.56 | 1.12 | 11.07 | 2.78 | 31.50 |
| 1939 | do a mile east of do do | 88.02 | 9.91 | 0.15 | 1.92 | 2.71 | 49.29 |
| 478 | Blanford, white, | 51.66 | 39.48 | 0.91 | 7.95 | 2.77 | 28.93 |
| 490 | Littleton, white crystalline, | 54.70 | 43.35 | 0.51 | 1.46 | 2.87 | 30.63 |
| 1944 | Sherburne, bowlders, white, | 60.43 | 29.84 | 2.36 | 7.37 | | 33.84 |
| 1918 | Concord, S. W. Part, gray, | 77.33 | 1.65 | 1.19 | 19.83 | | 43.30 |
| 1946 | West Natick, gray, crystalline, | 72.10 | 7.50 | | 20.40 | 2.75 | 40.38 |
| 1948 | do purer specimen, | 56.81 | 39.08 | 1.37 | 2.74 | | 31.81 |
| 1951 | do compact, yellowish, Rail Road cut, | 54.20 | 0.60 | | 45.20 | 2.68 | 30.35 |
| 1950 | do do do purer specimen, | 61.18 | 12.30 | 1.27 | 25.25 | | 34.26 |
| 1592 | Claystone, Hadley, | 56.60 | | | 43.4 | | 31.70 |
| 1651 | do North Adams, | 53.60 | 1.20 | | 45.2 | 2.60 | 30.02 |
| 1647 | do West Springfield, | 48.40 | | | 51 6 | 2.68 | 27.10 |

I consider the practical inferences which I shall make from the preceding table to be more important than from any other analyses which I have executed. But in this place I shall confine myself to the agricultural value of our limestones, and defer a consideration of their use as marble and cement to more appropriate places.

### *Is Magnesian Limestone useful in Agriculture?*

It has long passed for a settled principle that limestone abounding in magnesia is decidedly unfavorable to vegetation. But more accurate observations have led able writers to call this principle in question. Morton declares that in England, "although the soil is in general very thin on the magnesian lime, yet it is a good light soil for arable culture, and with manure produces good crops." (*Morton on Soils, p.* 80.) And Mr. Bakewell says, "I do not agree in opinion with those who regard the magnesian limestone districts as unfertile.—On the summit of Breedon Hill, in Leicestershire, I have seen a luxuriant crop of barley growing on land, that had borne a succession of twenty preceding crops without manuring. This is more deserving notice, being in an exposed and elevated situation, and upon the very hill of magnesian limestone which has been so frequently referred to by chemical writers, as

* I have reason to suppose that most of the limestone from this town is more magnesian than this specimen.

peculiarly unfavorable to vegetation. The limestone of this hill contains above 20 per cent. of magnesia.—The magnesian lime acts more powerfully in destroying undecomposed vegetable matter than common lime and its effects on land are more durable: hence it is in reality of greater value in agriculture, as a much smaller quantity will answer the same purpose." (*Bakewell's Geology, p.* 170, *and* 325.)

That a small proportion of magnesia is not injurious has always been admitted: a fact for which there is strong presumptive evidence in the existence of a small quantity of magnesia in nearly all soils. I strongly anticipate that the final conclusion on this subject will be, that land will bear less of magnesian than of common limestone: but that both are usually salutary. It is thought that generally lime is apt to injure until it has imbibed carbonic acid from the atmosphere, and is converted back into a carbonate, and it is also known that magnesia imbibes this gas more slowly than lime does; and this may be the reason why the former is more apt to do injury.

I have but one fact to state that has any bearing upon this question. It will be seen by the preceding Table, that the limestone burnt by Mr. Hadsell in New Marlboro,' is genuine dolomite; containing over 40 per cent. of magnesia. Now he informed me that some years since, he applied a large quantity of the quicklime derived from it, directly upon a piece of land with decided injury. But by subsequently applying a coat of manure, its productiveness was restored; and ever since it has been one of his best pieces of land. Such a fact seems to teach us, that a good deal of caution is necessary in the use of magnesian limestone: but it shows also, that with a proper amount of manure, it may prove a very valuable fertilizer.

### *Pulverized Limestone.*

If it be a fact that quicklime mixed with the soil very soon returns to the state of a carbonate; that is, to its condition before burning, then it may be successfully applied without burning. Except in those cases where it is desirable that the lime should act energetically upon undecomposed organic matter, to convert it into geine, it would be better to apply it unburnt; provided it be reduced to fine powder. The chief value of burning seems in most cases to be, to bring it into that state. But this can be done mechanically; that is, by grinding; just as gypsum is universally prepared. Now much of the magnesian limestone of Berkshire county is more easily reduced to powder than that which is pure; and that would undoubtedly be the best mode of preparing that kind of limestone for agricultural purposes. But since it may be doubted whether magnesian limestone is as good for vegetation as that which is pure, probably the inhabitants of Berkshire will

not think it best to use the former; since they have enough that is pure. Yet these suggestions respecting the grinding of limestone, are not inapplicable to that part of the state. For those immense accumulations of the fragments of pure limestone, that exist at some of the marble quarries there, as at West Stockbridge and Lanesborough, may probably be best converted into powder in this manner. Or if fuel is so abundant in the vicinity that it is cheaper to burn the stone, the time is not far distant when this cannot be the case. Besides, when the contemplated rail roads are completed in that part of the State, and the value of lime in agriculture is better appreciated than it now is, I hazard the prediction, that pure limestone will be an article of transportation to those parts of the state now deficient in that material.

In the eastern parts of the state, however, where fuel is much more expensive than in Berkshire, the grinding of limestone may be an object of more importance. Several quarries there, have indeed been abandoned from the high price of fuel. But in most instances water power for pulverization is accessible. The greatest difficulty in the way that I can think of, is the great hardness of several varieties of these eastern limestones. Perhaps, however, a description of the different localities will form the basis of a better judgment on this point. I shall now give such a description; more with reference to the economical value of our limestones, than to their scientific relations; although there is usually an intimate connection between the two things. I have sought for limestone in Massachusetts with far more care and effort than for the precious metals, because I believed it to be of far more value. The following statements will show that I have not labored wholly in vain; though I could have wished for better success.

### *Berkshire Limestones.*

In an economical point of view Berkshire county must be regarded as the principal mineral district of Massachusetts: and her limestone and iron form the principal mineral riches. Nothing can at all compete with these in any other part of the state, except perhaps the granites at Quincy and on Cape Ann. The vast amount of limestone in Berkshire may be seen by consulting the geological map. Nearly all the vallies abound with it, although it usually alternates with mica slate, or quartz rock. In many instances one travels for several miles across uninterrupted strata of limestone of good quality, either for agriculture, mortar, or marble. In short, the more familiar one becomes with the geology of the county, the more impressed he is with the inexhaustable amount of good limestone: and when we consider that these deposites lie upon the borders of a vast extent of

primitive country, stretching to the ocean on the east, where only a few scattered beds of limestone occur, we cannot doubt that those of Berkshire must prove an unfailing and increasing source of wealth as long as New England is inhabited.

It will be seen by the preceding analyses of our limestones that very many of those in Berkshire are magnesian. As a general fact I think the magnesian variety most abundant along the eastern part of the county, at the foot of Hoosac mountain; and the pure variety most abundant at the foot of the Taconic range. The mountains themselves with only a few exceptions, are composed of quartz rock or mica or talcose slates. In general, these limestones contain only a very small proportion of silica. In two examples of the magnesian variety, from Lee and Dalton, the rock perfectly dissolved in nitric acid: showing that it contained no silica. Only one other case of the kind have I met in the state; and that was a loose block found in Worthington, which was derived from Berkshire county by diluvial action. (See Table of Analyses.)

### *How to distinguish Magnesian Limestone.*

It would be very desirable to have some test of easy application for distinguishing the magnesian from pure limestone: for sometimes in Berkshire they constitute different layers of the same bed. Unfortunately, however, none but chemical tests furnish an infallible criterion. But there are some characteristics that will enable an intelligent man to detect the most perfect varieties of magnesian limestone, called dolomite, without the trouble of analysis. One is, that the texture of this rock is less firm than that of pure limestone; so much so, indeed, that it frequently crumbles down into sand, as may be seen in some places in Sheffield, and particularly in Canaan, the town in Conneticut next south of Sheffield. Another character of the dolomite is, that it is less distinctly stratified than pure carbonate of lime. This is strikingly exhibited in the limestone of Lee, which is mostly dolomite. A third and a better character is, that when pure limestone in the state of powder is thrown into diluted nitric acid (aqua fortis) it dissolves rapidly, and with powerful effervesence; so that in a few moments, if enough acid has been added, nothing remains undissolved but the earthy residuum. Whereas dolomite dissolves slowly, and hours are often required for its complete solution. Sometimes, however, when a limestone contains only a few per cent. of magnesia, it will dissolve very rapidly at first, but it will require a long time to complete the process: from whence it is inferred that pure carbonate of lime in such cases is mixed with dolomite; which is a double salt of lime and magnesia.

In some cases, it must be confessed, that the presence of magnesia in limestone cannot be detected but by going through with a careful analysis, which requires the apparatus and ingredients of a laboratory, and which the practical chemist alone can manage.

## *Middlefield and Becket Limestone.*

In ascending easterly the broad range of Hoosac Mountain from the valleys of Berkshire, the first beds of limestone which we meet lie in the east part of Middlefield, on the Pontoosuc turnpike; and on the line of the great Western Rail Road. The most westerly bed appears at the point where Cole's Brook empties from the north into a branch of Westfield river, on land of Gen. Mack. It is 5 or 6 rods thick, and is interposed between strata of gneiss, having a westerly dip of nearly 70°. One mile farther east, on the same branch of Westfield river, is another thick bed of limestone, of the same quality, lying between strata of gneiss, which lean a few degrees to the west. This stone often contains delicate serpentine, so intermixed as to form a beautiful verd antique marble when polished; as may be seen in Nos. 1954 and 1955. It is doubtful whether large blocks of this could be obtained: Yet as one of the sources whence a beautiful ornamental stone can be procured it ought not to be forgotten.

Both these beds of limestone extend southerly across the river into Becket, and one of them, probably the most easterly one, appears in the southeast part of that town, on what is called the Billy Messenger Farm, now owned by the State of Connecticut. Here formerly the stone was burnt into quicklime, as it has been more recently at the most easterly bed in Middlefield: but the kilns are not now in operation at either place: probably because the lime hence obtained cannot compete with the purer lime from the valleys of Berkshire.

The limestone from the three localities above named, (and I might add a fourth which I recently noticed two miles further south on the old Becket turnpike,) is very much alike in its general character; as may be seen in the table of analyses that has been given. The specimen from the most easterly bed in Middlefield is the most free from magnesia and earthy impurities: But there is great inequality in different parts of the bed as to purity, and much of it is rejected as too impure for burning. The fact is, the stone at these localities has been subjected to powerful heat at some former period, and is thereby injured for economical purposes. At present perhaps, it cannot be profitably burnt for the market. But as it exists in a region likely for a long time to abound in fuel, the time may come when this stone may be in demand.

The beautiful dolomitic limestone, a mile south of the meeting house in Tyringham, (No. 1924) which is extensively converted into quicklime, appears to be situated between strata of gneiss, just like the beds in Middlefield and Becket. The same is true in respect to some of the beds in New Marlborough, which are employed for a similar purpose: as at Hadsell's and Smith's quarries. (No. 1927, 1933.)

In the Table of Analyses a specimen is given (No. 2497) whose locality is Worthington, which was received from Dr. Brown of that place. Being informed that extensive ledges of it existed there, I analyzed the specimen; and found it to be the purest limestone which I had met with in Massachusetts. It will be seen that it contains no earthy matter, and no magnesia; and only an extremely small quantity of iron. I have since learnt that only bowlders are found in Worthington; and the probability is strong, that they were brought from Berkshire county.

I ought here to remark, that though in several instances no iron is given in the analysis, it is only because no attempt was made to separate it from the other ingredients, and I have reason to think it always exists in our limestones.

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### *Blanford Limestone.*

A small bed of limestone shows itself in the northwest part of Blanford, one mile south of a bed of serpentine, which, as well as the limestone, occurs near the junction of mica slate and hornblende slate; which last is narrow and succeeded by granitic gneiss. The character and composition of this limestone are very similar to that of Middlefield and Becket; and therefore additional description will be unnecessary.

### *Micaceous Limestone of Franklin and Hampshire Counties.*

In the mica slate region of Franklin and Hampshire counties, especially near its eastern border, a gray highly siliceous limestone occurs, which usually abounds also in mica. Indeed, it passes insensibly into mica slate, and is not generally distinguished from that rock. The table of analyses exhibits the composition of six specimens of this limestone; viz. two from Whately, two from Ashfield, one from Norwich, and one from Southampton, all of which contain a large proportion of earthy impurities; and one of them a little magnesia. I also ascertained the existence of magnesia in a specimen which I analyzed from Williamsburgh; which contained 63 per cent. of carbonate of lime.

This limestone is most abundant in the towns of Whately, Conway, Colrain, Buckland, and Ashfield: and in my former reports I suggested that some of it was pure enough to be burnt, especially for agricultural purposes. A company has since been formed, belonging to Hadley and Northampton, who have for several years burnt more or less of that in Whately, where occurs the largest and probably the purest bed of it that I know of. They have erected a perpetual kiln, and use the lime principally upon their land: and as they inform me, with good success. This is the first systematic and persevering effort, so far as I know, that has been made in Massachusetts to burn limestone for agricultural purposes: and hence deserves warm approbation and encouragement. This same stone, however, has been burnt in Buckland and applied successfully to land. But I believe its preparation is now abandoned. I have been told also, that it was formerly burnt on a small scale in Colrain. Some of it is obviously too impure to be profitably burnt, For in England a stone that does not contain more than 50 per cent. of carbonate of lime, is regarded as too impure for being profitably converted into quicklime. Hence if any are about to engage in burning this micaceous limestone, they should first resort to a chemist to ascertain the amount of lime which it contains. I shall have occasion to speak of the Whately lime in another place, as a valuable article for a particular kind of mortar.

I have conversed with most of the gentlemen concerned in the preparation of lime at Whately, who are all respectable farmers, and they assure me that the experiments which they have made with that lime upon their land, afford in most cases decided evidence of its good effects. Mr. Linus Green says he has tried it in a variety of ways, both upon grass and ploughed ground; and in such a way as to be able to judge of its effects; and in most cases it proves of marked benefit. Sometimes he has sowed it, after it had been slacked for some time, directly upon grass; or upon hills of corn, or potatoes; or has mixed it with loam, or with manure; and he rather prefers the latter mode. Mr. Nash and Son, have made numerous trials within a few years past with this lime, and the latter has been so good as to put down the facts upon paper: and as the experiments detailed seem to me to have been very well conducted, and the results important, I give his letter entire.

Sir,—You wish me to communicate to you any facts respecting the use of lime on my Father's farm which we may have observed.

We have had but little experience on this subject, having commenced using lime in the spring of 1837. The fall previous we had plowed a piece of low, clayey, pasture ground, which had, probably, never been plowed before. As we had intended to make some trial of the effects of lime on this piece, we had, in plowing, divided it into lands, the furrows of which ran east and west. As the land was soft we could not well do any thing with it till the fore part of June. At that time we carted upon the *south land*, ten loads of manure to the acre, of about 30 square feet each.

On the next land we put fifty bushels of lime to the acre; which, at twenty cents a bushel, (about its actual cost,) would amount to the same as the manure. On the north land we put no manure or lime. On the 11th. and 12th. of June, the whole was sowed with oats, seeded, and harrowed in.

In harvesting it was not convenient to keep the oats which grew on these several lands separate, so they were all mixed together,—our object being not so much to get the exact yield of each, as to satify ourselves by inspection and harvesting whether lime had an effect on land of this description. Of this we felt satisfied, for the oats on the land which had been limed were heavier and yielded a third more sheaves, than the land which had been manured,—though the yield there was considerably better than on land on which nothing had been put.

We have mowed these lands in 1838—9, and get as much in quantity and better in quality from the limed land than from both the others.

In the sping of the same year (1837,) we planted two pieces of potatoes on land of equal richness or as near as we could judge. One piece was manured in the hole with common barn-yard manure, at the rate of ten loads to the acre. The other was manured from a heap of compost which had been thrown together about ten days before using. Its composition would not, probably vary much from two thirds manure and one third loam with two bushels of lime added to a load. When it was used it was was all in a state of fermentation, though this had not proceeded so far as to destroy any of the manure. The same quantity was applied to the acre as before. This last piece yielded 250 bushels to the acre, while the former did not exceed 150. Perhaps this difference may appear to be great, but the land and potatoes were carefully measured.

In 1838, lime was mixed with all the manure which we intended to use on potatoe land, except a *part* of one piece, which was left further to test its effects. We did not measure the potatoes, but it was the opinion of my father, expressed at the time, that the same quantity of land limed yielded 1-3 more than the unlimed. The potatoe crop of 1838, you will recollect, was almost universally poor, both in quantity and quality. In either respect however, ours did not appear to be much inferior. This was probably owing in part to their being planted on low land, which enabled them better to resist the drought of that season. But the potatoes were evidently *better* on the limed than on the unlimed parts.

In 1839. we made no further experiments, having used lime for all our potatoes.

For the three last years we have used lime on mowing by mixing it with compost, and although we have never made an exact comparison of limed and unlimed parts by measuring the land and weighing the hay, yet the grass has evidently been better where the lime has been applied.

But whatever may have been the effects of lime on oats, grass and potatoes, we cannot see that it has benefited wheat or rye. Indeed we have been disappointed whenever we have applied it to either. In April 1838 we sowed ten bushels on 3-4 of an acre of winter rye. It appeared to kill most of the sorrel of which there was considerable among the rye, but the rye did not appear to be better than on land around it which had received no lime. On the 12th. of April, 1838, we sowed half an acre of wheat on a part of the piece which had the previous year yielded 250 bushels of potatoes to the acre. The 4th. of May, 20 bushels of lime were sowed

upon it, the blade being then about 3 inches high. We got only six bushels of wheat from the half acre, and that badly shrunk.

On the 6th. of Oct. of the same year we sowed one acre of winter wheat on old land, after corn. On this acre we sowed 45 bushels of lime and harrowed it in with the wheat. Part winter killed. The remainder grew remarkably well and promised a good yield, until it got into the milk state, when it commenced rusting. The crop was spoiled. So completely was the kernel robbed of its nourishment and shrivelled up that it was hardly worth thrashing. Only 3 1-2 bushels were thrashed from the whole of it. It may, perhaps, be proper to inform you that this piece after turning under the stuble was sowed with turnips. As they were sowed late we did did not expect much of a crop. We gathered something over 150 bushels of first rate roots remarkably free from worms.

Last spring we sowed one bushel of Italian-spring wheat on 95 rods of land and seeded it down. About a fortnight after 10 or 11 bushels of lime were sowed upon it. There was a large crop of straw, sufficient to have yielded 25 bushels per acre. But it was affected by the rust and we got only eight bushels from the piece, which would be 13 1-2 bushels per acre, nearly. The clover and herdsgrass look remarkably well.

All the lime we have used was burned at Whately. The cost of fuel for burning in the draw kiln has varied from three to four cents a bushel. Wood, half hard and half soft, 4 feet long has usually cost from 9 to 10 shillings per cord. The Company pay 6 1-2 cents a bushel for quarrying and burning.

Very Respectfully yours.
SAMUEL NASH.

PROF. E. HITCHCOCK.
*Hadley, Dec.* 3, 1839.

## *Limestone of Whitingham, Vermont.*

I mention this bed of limestone, first because it is so extensively used in Massachusetts, and secondly because it very probably extends into Massachusetts. It lies in the south part of Whitingham, near the junction of talcose slate and gneiss, and in external character resembles that in Middlefield and Becket, though perhaps rather more pure. I have not analysed it, but cannot doubt that it contains magnesia.

## *Limestone of Bernardston.*

This limestone is associated with a bed of magnetic iron ore: and some 40 or 50 years ago, an attempt was made to smelt the latter, making use of the former for a flux. But not being very successful, very probably from the presence of some oxide of manganese, the enterprise was abandoned; and it was not till a few years ago that any effort has been made to burn the limestone. As we might presume from the analysis, it produces a very good lime for cement, and doubtless good also for agriculture. A good deal of hydrate of iron is occasionally intermixed with the limestone, which gives the lime a dark color: but this is not probably of any injury when it is employed for mortar. The bed is of considerable extent and obviously of a more recent age than the limestone that has been described: for it contains some organic remains.

## *Fetid and Ferruginous Limestones of Hampden County.*

These occur in the bed of Chicopee River, at the Chicopee Factory Village, in Springfield, and in West Springfield on the banks of Agawam river; and also in the northeastern part

of the town. Two quarries have been opened at the latter locality and the fetid limestone burnt to a considerable extent for hydraulic cement, by Mr. Paine. But the ferruginous limestone, which often exists in the form of septaria, has never been used at all. Nor have any of these limestones that I can learn, ever been employed in agriculture; although I cannot doubt but they would answer admirably well. I shall have occasion to refer to them again when I treat of the application of our limestones for cements. I would only remark here, that though the beds of these limestones which exist in the red sandstone formation, are thin, yet most of them are extensive, and will last for a long time.

### *Limestone in Belchertown.*

About a mile southeast of the village in Belchertown, a bed of limestone occurs in gneiss: which at the surface appears of no great extent: and most of it is impure, though sometimes highly crystalline. It has never however, been explored to any extent: and not unlikely it may hereafter be found of value.

### *Limestone of Bolton, Boxborough, Acton, Littleton, Carlisle, Chelmsford, Natick and Sherburne.*

I notice all these beds of limestone together, because they occur in the same rock, and are very much alike in their characters. They are generally white crystalline limestones, highly magnesian, and almost destitute of stratification; placed between highly inclined strata of gneiss. The rock is usually very much mixed with foreign minerals; such as scapolite, serpentine, compact feldspar, &c. although such portions are mostly rejected. None of the beds are of any great extent in the direction of the strata; nor is their width more than a few yards in any case. Most of them have been opened at different periods, and the stone burnt into quicklime; but nearly all of them are now abandoned; probably because the price of fuel has so increased that lime may be obtained at a cheaper rate from a foreign market. At Bolton, however, a good deal of limestone is still burnt.

In several of these towns, as Chelmsford, Bolton, and Natick, there are several beds of this rock, more or less remote from one another. In the latter place, the rock was formerly dug and burnt during the revolutionary war, from a bed a mile or two northeast of the meeting house; and more recently some of it has been ground for use upon land. No. 1946, shows the composition of this rock. A much purer and highly magnesian specimen, was dug out at the rail road excavation near the same spot, of which No. 1948, in the Table of Analyses, shows the composition. In the same cut a yellow compact limestone was discovered, which forms a bed 4 or 5 feet thick, of which Nos. 1950, 1951, give the composition. The specimen analyzed from Sherburne, was found a short distance southeast of the meeting house; where it occurs in numerous blocks in the stone wall: but I did not discover it in place. And as this spot is nearly south from West Natick, where the limestone above described is found, it is possible that the Sherburne stone may have been brought from that place by diluvial action. More probably, the Natick bed extends to that place beneath the soil, and not improbably a little research might discover it. And really, I regard the discovery in any place in New England, of a good bed of limestone, as of more importance then a mine of gold: for though at present in the eastern part of Massachusetts most of the lime used is brought from Maine, yet the time must come when the price of this foreign supply will be so high, that the inhabitants will be obliged to re-explore the now deserted beds of this rock.

### *Concord Limestone.*

In the southeast part of Concord, on the bank of a branch of Concord river, where it is crossed by the great road leading from Boston to Bolton, I recently found gray limestome in hornblendic gneiss, forming beds from a few inches to several feet in width. It is impossible to determine without excavation, whether enough of good limestone could be found here to make it an object of economical interest. This limestone so much resembles the including rock, that they are apt to be confounded, especially when obscured by disintegration and lichens. It will be seen by the analysis, that this limestone is almost free from magnesia: and that it does not contain so much of siliceous impurity as to make it unprofitable for burning.

### *Limestone of Stoneham and Newbury.*

I put these beds together because they both occur in sienite or perhaps in a rock intermediate between hornblendic gneiss and sienite. The Newbury limestone, of which there are several beds not far from one another, resembles that already described in Bolton, Natick, &c. But that at Stoneham is a beautiful white compact stone, well adapted, were it free from fissures, for statuary marble. It contains, however, more than its appearance would indicate, of silica; and is considerably magnesian. The limestone both of Newbury and Stoneham has been extensively excavated in past time, but is now neglected. Yet let it not hence be inferred that it will never come into use.

### *Limestone of Walpole and Attleborough.*

In both these towns I suppose the limestone to be associated with the rock usually denominated graywacke. That in Attleborough is certainly thus situated: forming a bed, perhaps only a few inches, but probably a few feet wide, in the red slate, in the southwest part of the town, on land of Thomas Arnold. As I noticed blocks in the vicinity quite frequently, I suspect that it may occur there in large quantity: and the analysis shows it to be a very pure limestone. The bed in Walpole lies in the southwest part of the town, and was formerly explored and burnt. It is of a gray color and contains a good deal of siliceous impurity.

The greater part of the quicklime used in the eastern part of Massachusetts, is brought from Thomaston in Maine; and from Smithfield in Rhode Island. The quarries in the latter place are only a short distance from Massachusetts; and the stone being of a good quality, it is extensively wrought. A few years since 20.000 casks of lime, containing from 38 to 40 gallons each, and selling at $2 per cask,—was put up in Smithfield. There are two beds of the rock, about 2 miles apart, in hornblende slate. The color is white and the texture crystalline.

Perhaps I ought to mention, that among the slate of the stone walls in the west part of West Newbury, I noticed blocks of white limestone (No. 1945). Probably they are derived from a bed at no great distance; as they were not rounded; and careful examination might bring it to light.

I doubt not but many of the above localities of limestone will be new to most of our inhabitants, as they were to me a few years since. I have felt it to be important to describe them all, in the belief, that though now in a great measure neglected, they will ultimately be regarded as of no small value.

The three last specimens, whose analysis is given in the Table, are those singular concretions

called claystones, which are common in our clays; and which appear to contain about 50 per cent. of carbonate of lime. They occur in too small quantity to be of much economical value; and I shall, therefore, reserve a description of them to the more exclusively scientific part of my report.

## II. SUBSTANCES CONTAINING LITTLE OR NO CALCAREOUS MATTER, BUT OPERATING UPON SOILS VERY MUCH LIKE LIME.

### 1. *Green Sand.*

This substance constitutes a large part of what in New Jersey goes by the name of marl; and which, within a few years past, has wrought such wonders in some parts of that State. It is found also in Virginia, and probably exists in all the Southern States, that extend to the Atlantic. In my report of 1834, I described this substance as forming a bed of considerable thickness at Gay Head, being a part of the tertiary formation there. I also intimated in the same place, that probably it existed on the continent at Duxbury. This point I determined if possible to settle, and proceeded to Duxbury accordingly. And in the extreme north-westerly part of the town, or rather for the most part within the bounds of Marshfield, about two miles southwest from the seat of Hon. Daniel Webster, I found the spot described by Rev. Mr. Kent, as given in my report. I was surprised to find the region abound in low hills of granite, with occasionally a swamp or small stream; being in fact, as unpromising a spot for green sand as I had seen in the State. Yet here I found that the green sand had been thrown up from at least three wells; one of which (on widow Sprague's place,) is in Duxbury, and the other two in Marshfield, near a small stream called South River. In the well on Mr. Kent's farm, (that described in my report as in Duxbury,) the green sand was struck at the depth of 13 feet from the surface. In the other, that on the farm of John Chandler, Jr., it was struck at the depth of 21 feet; and the bed was five feet thick. This spot was nearly 20 feet above South River; and it occurred to me that perhaps on the margin of the stream the sand might be found, just beneath the surface. I caused an excavation to be made there, and after passing through one foot and a half of black mud, and the same distance through yellow sand and gravel very much consolidated, I had the pleasure of reaching the green sand. This spot is perhaps 15 or 20 feet above tide water. An extensive swamp extends from this place through the west part of Duxbury several miles, and I have reason to suppose the green sand may be found along its whole extent. Indeed, I strongly suspect that it occurs abundantly along the coast from Marshfield to Plymouth, and not improbably also on Cape Cod. The general aspect of a large part of Plymouth and Barnstable counties is very much like the region where this substance occurs.

The coloring matter of this sand forms but a small proportion of the whole mass wherever it has yet been found; yet it imparts a decided green tinge to the whole. The specimens which I obtained at Marshfield, however, contained probably much less than the average quantity of the green matter. For some of it had been exposed to the action of rain, &c, for several years; having been formerly thrown out of a well; and that from the excavation which I made, was obtained only a few inches below the upper part of the bed. The specimen in the State collection, (No. 158,) bears a stronger resemblance to the green sand found on the continent of Europe, than to that from New Jersey. It became a point of much importance to identify this with other green sands. This could be done only by chemistry: and I am happy to be able to present here the very accurate results of analysis, which Dr. S. L. Dana, at my request has obtained, whereby the identity of this green sand with that of Europe, is completely established.

"The *green sand* from Marshfield," says he, "was treated as follows to separate the green particles. Washed in a large volume of water, the black brown, and green particles subside, mixed with many quartzy grains. The grains form about one half the whole bulk. These grains were then washed in a smaller quantity of water, and the attrition caused the water at each successive washing, to become ochrey, and I began to think that I should wash nearly all away.* I then treated the grains with dilute muriatic acid—washed them anew, dried and passed them through a sieve. The whole looked like mustard seed, with a few light green particles here and there among the black, green, and brown particles and quartzy grains. Pulverized, the whole becomes ochre brown. It was dried at 212°, and the analysis conducted as usual, gave—

| | |
|---|---|
| Water, | 6.50 |
| Black Oxide Iron, (ferroso-ferrique of Berzelius,) | 64.944 |
| Alumina, | 4.372 |
| Silex, | 23.0 |
| Lime, | 0.536 |
| Magnesia, | 0.648 |
| | 100. |

"The earths, if silicates, will require 4.721 silex; and on no supposition will the remaining silex and water convert the iron into a hydrated silicate. Hence the iron is not combined with the silex, but exists as a hydrated oxide of iron. The composition will then be; free silex, 18.289; hydrated oxides of iron, 71.444; silicates

$$\text{of}\ \frac{\text{alumina, } 4.372}{\text{silex, } 3.886} + \text{of}\ \frac{\text{lime, } .535}{\text{silex, } .316} + \frac{\text{magnesia, } .648}{\text{silex, } .519} = 10.277.$$

* The specimen which I sent Dr. Dana, had probably lain upon the surface of the ground for several years, and the iron had most likely become somewhat peroxidized."

If we allow the hydrated iron to be mixed, a portion with the above silicates, except the lime, which Berthier and Turner did not find essential in their analyses of the coloring matter of green sand, we have a small portion of this coloring matter mixed with a large portion of hydrated oxide of iron. Only about 5 per cent. of the whole is green sand, similar in its composition to that examined by the late Professor Turner, as stated in Dr. Fitton's "Remarks on the Strata below the chalk, &c., in the south east of England;" p. 108.

In a subsequent letter, Dr. Dana gives the result of his analysis of the green sand from Gay Head, of which No. 72 in the State collection, in the rooms of the Boston Natural History Society, is an example. This gives a better idea of the ordinary appearance of this substance than the specimen from Marshfield.

"I have finished the Vineyard green sand. It is very near the results of Turner. I washed the whole in water, poured off the light part, washed the remainder repeatedly, reserving the washing, which let fall a fine powder of a decided green tinge, feeling, when dry, under the pestle, like soapstone powder. The residuary quartzy grains were rejected, a few fine green particles among them. The second portion alone, was taken as the best sample of coloring matter, and gave—

| | |
|---|---|
| Water, | 7.000 |
| Silica, | 56.700 |
| Alumina, | 13.320 |
| Oxide of Iron, | 20.100 |
| Lime, | 1.624 |
| Magnesia, | 1.176 |
| Manganese, traces, and loss. | 0.080 |
| | 100. |

"The water and iron are nearly the same, the alumina the mean, and the silica about 6 per cent. more, than the analysis of Turner and Berthier. No doubt therefore it is a true green sand."

The above analyses do not give the actual per cent. of this green substance in the soil where it is found, though it evidently cannot form a large proportion. But this is not necessary in order that very decidedly good effects should result from its use in Agriculture. The following extract from the report of Professor Henry D. Rogers, on the Geology of New Jersey, bears on this point as well as upon the general value of green sand in the cultivation of the soil.

"When we behold," says he, "a luxuriant harvest gathered from fields where the soil originally was nothing but sand, and find it all due to the use of a mineral sparsely disseminated in the sandy beach of the ocean, we must look with exulting admiration upon the benefits upon vegetation, conferred by a few scattered granules of this unique and peculiar substance. The small amount of green sand dispersed through the common sand, is able, as we behold, to effect immeas-

urable benefits in spite of a great predominance of the other material which we are taught to regard as by itself so generally prejudicial to fertility. This ought to exhibit an encouraging picture to those districts not directly within the limits of the marl tract, where some of the strata possess the green substance in sensible proportion. It expands most materially the limits of the territory where marling may be introduced and points to many beds as fertilizing, which otherwise would be deemed wholly inefficacious."

In another place of his most valuable Report, Prof. Rogers says, that "Mr. Woolley manured a piece of land in the proportion of two hundred loads of good stable manure to the acre, applying upon an adjacent tract of the same soil his marl in the ratio of about twenty loads per acre. The crops, which were timothy and clover, were much the heaviest upon the section which had received the marl, and there was this additional fact greatly in favor of the fossil manure over the putrescent one, that the soil enriched by it was also entirely *free of weeds*, while the stable manure had rendered its own crop very foul." Placing the home value of the farm yard manure at one hundred cents for each two horse load, and that of the marl at twenty-five cents per load, we have the expense of manuring one acre 200 dollars, of marling the same 5 dollars." "Land which had been sold at 2 1-2 dollars per acre, in consequence of the permanent increase in its fertility from the marl, is now worth 37 dollars the acre."

There is one fact, however, that will throw a doubt over the probable utility of this substance in Massachusetts. By taking the average of eight very accurate analyses of the New Jersey green sand, as given by Prof. Rogers, we find that it contains 10 per cent. of potassa. Mr. Seybert's analysis gave nearly the same amount, and Mr. A. A. Hayes informs me that in two varieties analyzed by himself, he found 7 per cent. of dry oxide of potassium. But only a trace of potassa was found by Dr. Dana in the Massachusetts green sand, which, in this respect, compares with the English green sand analyzed by Prof. Turner. Now Prof. H. D. Rogers imputes the value of this substance in agriculture almost exclusively to the potassa which it contains; and no chemist will doubt but that this ingredient will exert a very salutary influence upon soil. Yet there are other ingredients in the green sand, which some will suppose may increase its fertilizing power. One of these is the protoxide of iron, whose quantity is large, and which Prof. William B. Rogers, of Virginia, supposes may be of service, by its alkaline character, upon vegetation. This view will receive confirmation by some facts and reasonings that will be presented when I come shortly to speak of the application of clay in agriculture. It is probable, also, that the lime and magnesia in the Massachusetts green sand, may aid in a similar way. That all the good effects of this substance upon soil in New Jersey cannot be imputed to the potassa, seems probable, from the fact that granite and gneiss contain quite as large a proportion of potassa, and when spread in a powdered or decomposing state upon the soil, ought, therefore, to fertilize as much as the green sand; especially as Mr. Hayes informs me that the New Jersey green sand "decomposes in nitric acid slowly, being less soluble than some feldspar." But there is no evidence that the good effects of the granite and gneiss are as great as those of the green sand; and hence we must call in the aid of some other ingredient to explain its fertilizing power.

I do not, therefore, despair of our green sand in agriculture. It certainly deserves a fair trial, when we consider what a change this substance is producing in much of the poorest land in New Jersey and Virginia. It would be very easy to obtain an abundance of it at Gay Head, where it occurs in great quantities, towards the north end of the cliff. Or I doubt not but it may be found in many places along the coast in Barnstable and Plymouth counties, a few feet beneath the surface, in the lowest places. Very likely a little research may bring to light varieties that contain potassa; and should this be the case, the change that might thereby be produced in the agriculture of the south-east part of Massachusetts, can hardly be calculated.

After Dr. Dana had favored me with the analysis of the Green Sand of Massachusetts above given, it occurred to me, that as I took the specimens from near the surface, it was possible they might have lost their potassa by the action of atmospheric agents, and I accordingly visited Gay Head again, and obtained specimens at some depth from the surface. These I subjected to analysis, by the method recommended by Prof. Henry D. Rogers, in his Report on the Geology of New Jersey, p. 93. A portion of this sand (No. 208) was washed three or four times, and the lighter part poured off. The residue consisted of grains of quartz and green sand: 30 grains of which yielded as follows:

| | |
|---|---|
| Water, | 2.70 |
| Silica, | 19.80 |
| Protoxide of Iron, | 5.80 |
| Alumina, | 1.20 |
| Lime, | 0.17 |
| Loss, | 0.33 |
| | 30.00 |

30 Grains of the washings, treated in the same manner, yielded. as follows:

| | |
|---|---|
| Water, | 4.10 |
| Silica, | 18.90 |
| Alumina, | 2.20 |
| Protoxide of Iron, | 4.25 |
| Lime, | 0.11 |
| Loss, | 0.44 |
| | 30.00 |

I could not discover a trace of potassa or magnesia. By visiting Gay Head, I ascertained that the stratum of green sand there has a northeasterly dip of about 40°; and that measured horizontally on the beach, its thickness is about 50 feet; so that the quantity is very great should it ever prove of any service.

## 2. *Clay.*

There is abundant evidence that our common clays are of great value when spread upon land. I find that they have been used to a considerable extent in the state; so commonly, indeed, that I abandoned the idea I had formed of giving a detailed account of particular instances. So far as my inquiries have extended, the testimony is decided that our blue clays exert a very favorable effect upon the soil. When spread upon sandy ground we might expect that they would render it a better reservoir for salts and geine. But thoroughly to ameliorate our sandy soils in this way, requires far more clay

than is usually employed, and I am perfectly convinced that they exert other than a mechanical influence; that in fact, their effect is analogous to that of lime. I refer here to the blue clays which are far the most common. As to the white clay I have not learnt its effect upon the soil; but from the fertility of some of the soils in Kingston, Plymouth, and Barnstable, where white clay is mixed naturally with sand, I presume this sort is equally valuable with the blue.

In view of the wide extent of our beds of clay, and the use that might be made of it upon land, I felt desirous to ascertain to what principle it owes its fertilizing powers; and therefore subjected a few specimens to analysis in the ordinary way by fusion with alkali. The following are the results. I omit however certain white clays, which I found destitute of iron, and therefore probably not very likely to be of much value upon land. But for other purposes, of which I shall speak shortly, they are of a good deal of importance.

*Analysis in the Dry way by Alkali.*

| No. | LOCALITY. | Water and Organic Matter. | Silica. | Alumina. | Prot-oxide of Iron. | Oxide of Manganese. | Lime | Magnesia. | Sulphur and Loss. |
|---|---|---|---|---|---|---|---|---|---|
| 139 | Northfield; blue. | 10.8 | 46.93 | 28.97 | 9.9 | | | 0.1 | 2.9 |
| 140 | Sunderland; light blue. | 8.2 | 49.00 | 29.15 | 13.1 | 0.15 | slight precip. | 0.4 | |
| 142 | Kingston; white. | 3.5 | 71.00 | 16.30 | 7.3 | 0.30 | do | 0.3 | 1.3 |
| 143 | Lowell; white. | 4.0 | 61.52 | 20.50 | 9.2 | 0.56 | 0.56 | 0.44 | 3.29 |

I tried some of our blue clays also, for geine; but in general they yielded only very little, and perhaps none. For so strongly do they retain water, that not improbably all the loss, especially of soluble geine, might have been imputed to this substance, which had not been all expelled by a heat of 300° F.; and then the peroxidation of the iron by ignition, renders this method of analysis quite uncertain. I, therefore, omit the results; only observing, that the amount of sulphate and phosphate of lime obtained, was about the same as in good soils. I therefore suspect that we must impute most of the good effects of clay as a manure to the large quantity of iron which it contains. On this point, however, I will present some suggestions of Dr. Dana, with which he has kindly favored me.

"If we attempt," says he, "to account for the action of *clay*, independent of its amending a sandy soil, we should bear in mind that all our common clays contain more or less of sulphuret of iron. The conversion of this into

the persulphate of iron is the natural consequence of exposure: free sulphuric acid then results, which acts on any lime in the soil, forming sulphate of lime: (the Gay Head crystals of sulphate of lime are so formed:) so that by spreading clay, we spread plaster. The iron in clay also plays its part thus. It is evident from Chaptal's experiments, that protoxide of iron is not beneficial in agriculture. He attributes this to the oxidation of the iron, depriving the plant of its intended oxygen. Nature is no niggard; nor is the reason of Chaptal very philosophical. We have seen above that protoxide of iron does not act on geine. Now by exposure, the protoxide becomes peroxide; and then, I conceive begins an action similar to that of lime. If the free sulphuric acid, produced as we have supposed, finds not lime enough, it will decompose all earthy geates, and thus a fresh portion of nutriment is set at liberty. Both the effects of clay—the production of plaster and the formation of peroxide of iron, are speedily produced by burning the clay, as is often practised."*

Still more recently, Dr. Dana adds the following: "Some facts have lately come under my eye, and have recalled others to mind, which I have followed up experimentally; all tending to show, *that if iron peroxidates itself in contact with vegetable fibre, the texture of the vegetable fibre is weakened*, and geine is produced, and that *in a few hours. It is during the passage from protoxide to peroxide, that the 'saponifying' action takes place*, geine is produced, and then *combines with peroxide.*"

In the few analyses which I have given above of our clays, I have considered all the iron in them as existing in the state of protoxide; although I made no attempt to ascertain whether some of it might not be a peroxide. Very probably this may to some extent be the case: especially where the clay has a yellowish tinge. Yet for the most part, I doubt not it is a protoxide. A slight error here cannot affect the reasoning above presented.

I hope our farmers will make more numerous and accurate experiments upon the use of clay as a manure; not merely upon sandy land, but following the suggestion of Dr. Dana, upon other soils, in the expectation that its action will be analogous to that of lime. Probably, the best clay for this

* The agency of geine in the fermentation of manure is thus explained by Dr. Dana with his usual clearness and felicity.

"By fermenting dung vast volumes of ammonia are liberated. I do not think that it is the action of gases as such, which we want, or which nature intends as food of plants to be derived from the soil. The air is always full of all which the fermenting manure can supply in a gaseous form. The true actions of ammonia and carbonic acid resolve into their effects on geine. The ammonia combines as alkali with that, and thus it becomes very soluble, and the carbonic acid produces sur-salts of the earthy geates of lime and magnesia. It is these, liberated the moment the plant demands them, which cause all the geine of the manure to become alcaline soluble geates."

"How wide is the influence of geine! It not only enters by itself into the food of vegetables but becomes the very solvent which nature has prepared to act on the alkalies, earths and oxides, dissolving them as they are liberated from decomposing granitic sand."

purpose occurs in the valley of Connecticut river; but it abounds in almost every part of the state, and perhaps it may in a good measure supply the deficiency of lime. It will of course require to be laid on in much greater quantity than marl, and probably, as in the case of marl, too much may be used. How much ought to be used is a fair subject for experiment.

### 3. *Decomposing Rocks that contain Feldspar.*

Feldspar and mica contain quite a large proportion of potassa; a substance well known to be valuable in agriculture. And these minerals constitute a large proportion of several of our most common rocks; such as granite, sienite, greenstone, porphyry, gneiss, mica slate, and graywacke. Hence we might predict that these rocks, recently decomposed or reduced to fine powder, would form a good dressing for land; especially when we reccollect that the same rocks contain a fair proportion of iron. Now some varieties of them are very liable to decomposition: and when partially crumbled down, if ground in a plaster mill, they will be brought into a proper state for such a use. These suggestions, however, are more the result of theory than of actual experiment: although such a use of powdered rock has sometimes been made and found of value. Indeed, an example of the good effects of decomposing gneiss upon cultivation was pointed out to me in the south part of Athol: and No. 100 presents a specimen of this substance, obtained nearly a foot from the surface in a ploughed field, but not below the point to which geine had penetrated; as appears from the analysis. Yet as this is insoluble it could not affect the vegetation but slightly. The salts of lime also are not in large proportion, and very probably its good effects, which were not represented as great, may have chiefly resulted from the liberation of potassa from the mica and feldspar.

Now there is a great deal of partially decomposed rock in the formations of this State, which have been named above, and they constitute at present the most barren spots in our soils: because they are not reduced fine enough to form a good soil; or because they are too strongly impregnated with stimulating salts. Perhaps if spread over soils already containing geine, they might operate favorably upon crops. At least, it seems to me there is so much plausibility in the theoretical suggestions above made that it would be desirable to make this experiment on a small scale, since it is so easy, even if it be necessary to reduce the crumbling rock to powder in a mill. In England decomposing trap rock is mixed with lime, and forms a valuable dressing for land. *De la Beche's Report on the Geology of Cornwall and Devon. p.* 471. Those who have farms on the trap ranges of the valley of Connecticut river, would do well to try this experiment.

### 4. *Hydrate of Silica.*

In describing our marls I have already referred to this substance, which is quite common beneath our peat bogs. In its purest state, as it exists in No. 157 from Spencer, it exceedingly resembles carbonate of Magnesia, in color, levity, and taste; although easily distinguished by chemical tests. When mixed with some vegetable matter, as in Nos. 162, 170, and 171, from Barre, Andover, and West Bridgewater, its color is darker This is its most usual mode of occurrence: and I doubt not but it exists in considerable quantity in every town in the state. In addition to the localities named above, I have specimens from Manchester, Sturbridge, Fitchburg, Wrentham, and Pelham. Usually it is found in layers only a few inches thick: but sometimes its quantity is much greater. Mr. Alonzo Gray of Andover, describes one bed in that place, as 17 feet in thickness, beneath a layer of peat from 2 to 6 feet, extending over an area of sixa acres. For one or two feet immediately beneath the peat at this spot, this peculiar substance is mixed with vegetable matter, and this is considered worth half as much as manure for land. It has been used somewhat extensively in this and other New England States as a fertilizer, and with decided benefit. With a view to ascertain what principle gives it value upon land, I subjected two specimens to analysis. The first was the pure white variety from Spencer, No. 157, which afforded the following results in 100 parts, by fusion with 2 parts of carbonate of Soda and 3 parts of carbonate of potassa.

| | |
|---|---|
| Water, | 12.00 |
| Silica, | 81.14 |
| Alumina, | 5.61 |
| Peroxide of Iron, | 0.59 |
| Lime, | 0.12 |
| Magnesia, | 0.24 |
| Manganese and loss, | 0.30 |
| | 100.00 |

A specimen from Barre (No. 169) gave the following results.

| | |
|---|---|
| Water, | 12.00 |
| Organic Matter, | 3.0 |
| Silica, | 66.42 |
| Alumina, | 9.40 |
| Peroxide of Iron, | 6.11 |
| Lime, | 1.01 |
| Magnesia, | 1.41 |
| Loss, | 0.65 |
| | 100.00 |

From these analyses we perceive that this substance is essentially composed of silica and water; and is hence, in scientific language a hydrate of silica. The specimen from Spencer did not change its color when ignited, and therefore contains no organic matter, either vegetable or animal: but that from Barre became black when strongly heated; showing the presence of such matter. Assuming the water to be the same as in the Spencer specimen, I hence determine the amount of organic matter to be 3 per cent.

From these analyses we can discover only two circumstances that can give this substance value as a manure: the first is, the presence of organic matter, probably in a very favorable state for promoting the growth of vegetables; the second is its remarkable hygrometric properties, which might make it especially valuable upon dry soil, or in time of drought. The latter of these properties only, can give any value to the Spencer specimen. But since the publication of my report of 1838, I have ascertained the astonishing fact, that the siliceous part of this substance is made up entirely of the shields or skeletons of animalculæ, that once lived and died in the waters from which it was deposited!* And perhaps in this fact we may see another cause for the fertilizing power possessed by it. It may be that some of the soft animal matter, that once covered these skeletons, still remains for the nourishment of plants. At any rate, it must henceforth possess a high degree of scientific interest. But this is not the place to discuss the subject in that light.

If it be desirable to give this substance a less technical name, than the chemical one prefixed to this article, it will be very proper to denominate it *Siliceous Marl.*

## III. NATURAL SOURCES OF GEINE, OR VEGETABLE NUTRIMENT, IN MASSACHUSETTS.

Having now pointed out the situation and value, so far as known, of all the calcareous deposites in the State that can be applied to agriculture, and of other substances whose action on soils is somewhat analogous to that of lime, the next grand inquiry is, whether there are any sources in the earth from which additional quantities of geine can be obtained, or matters convertible into geine. I pass by the whole list of common manures, presuming that they will be fully discussed by the Agricultural Surveyor. And I

* We are indebted to Prof. Bailey of West Point for having first ascertained that the Hydrate of Silica in this country beneath our peat bogs, is constituted of the remains of animalculæ: a discovery of very great interest to Geology. See *American Journal of Science, Vol.* 1. *p.* 118.

shall merely notice the natural sources of vegetable nutriment within our limits.

## 1. *Peat and Mud Swamps.*

The peat and muck mud swamps of New England have become a vast repository of organic matter, which is, and has been, for ages increasing. In addition to the larger vegetables, which, as they die, fall and are enveloped in the soft matter on which they grew, there is a thick mat of moss, which —especially the sphagnum—continues to flourish at the upper part while the lower part dies and decays. In favorable circumstances as to wet and temperature, this mass of vegetable matter becomes converted into peat. Only a small part, however, of what is accumulated, becomes peat of such a character that it answers well for fuel. Often it is too much mixed with mud to be easily burnt, and sometimes the vegetable fibre is scarcely changed. Yet the whole of it is capable of being converted into vegetable nutriment. And I am convinced, from all that I have seen and heard, that Massachusetts contains enough of this geine and vegetable fibre in her swamps, to render all her fields fertile for centuries. In other words, here is an exhaustless source of geine. Some of it is already in a soluble state; and therefore the black matter from swamps, is rarely spread upon soils without producing some benefit. Yet for the most part the geine is in such a state as to require some chemical change before it will become soluble nutriment, fit to be absorbed by roots. It is an important inquiry then, what is the best mode of accomplishing this change. This has been attempted, first, by mixing the peaty matter with good manure in alternating layers, and suffering them to ferment for a long time, the peat being in much the greatest quantity: Secondly, by mixing it in a similar manner with lime; or with lime and manure: and thirdly, by mixing it with alkali, or some compound containing alkali. The principles respecting geine which have been advanced in this Report, will probably enable us to decide as to the preference to be given to any one of these methods. And here I have it in my power to give the opinion of Dr. Dana, whose remarks I am always happy to substitute for my own, on a subject with which he is so familiar, and which he has done so much to elucidate.

"The fact," says he, "that peat or turf is very soluble in alkali, seems not to be known among our farmers. The usual practice of mixing lime with peat or turf is decidedly the worst which can be followed. The geine which constitutes a large part of peat bogs, forms with lime a compound little soluble in water, requiring at least 2000 parts of water to one of geate of lime: and if the compound has been dryed and sun-baked, a still larger por-

tion of water is required: it becomes, in truth, almost insoluble. With alumina, geine forms a compound still more insoluble than with lime; and though the vegetable matter in combination with these earthy bases, is actually absorbed by the roots of growing plants, still the geine is in a state much less favorable than when in combination with alkali. Mix ley of wood ashes with peat, and we form a dark brown vegetable solution: the alkaline properties are completely neutralized by the geine, and very often ammonia escapes from turf when treated by caustic alkali. When we add, that this geine absorbs and retains nearly its own weight of water without seeming moist, it is evident, that with the use of ley or wood ashes, the value of peat as a manure will be much increased."

Dr. Andrew Nichols of Danvers, having had his attention called to the subject by Dr. Dana's remarks in my Report of 1838, performed some interesting experiments with peat mud and alkali in 1839, according to the preceeding suggestions of Dr. Dana. He made use of ashes and potassa; mixing them with the mud, and applying the compound, both in a dry and a liquid state, upon Indian corn, barley, and onions. So striking was the effect, most so upon the onions, that the committee of the Agricultural Society of Essex County awarded to Dr. Nichols a premium of 20 dollars. For the details of this case see the *Transactions of the Essex County Agricultural Society for* 1839, *p.* 35.

In the northeast part of Amherst, Mr. King has a farm underlaid by coarse granite, which has proved as productive as any in the region: and I find that he makes little use of manure: but employs the muck mud from a peat swamp. And he usually spreads it over his land directly from the swamp. But he finds that he must use that which lies two or three feet below the surface, and which has a reddish tinge; and this is fully equal to the same amount of manure: He says that this, when exposed for some time to the air, becomes covered with an efflorescence some sort of salt. Probably this fact may explain in part why mud is best, which is dug from the depth of a few feet.

From these facts may not the farmer derive some valuable hints? May he not find that generally, the lower portion of the muck in his swamp, is in a fit state to be spread at once upon his land; without the trouble of forming with it a compost?

The two principal ingredients of peat are soluble and insoluble geine. It often contains also undecomposed vegetable fibre, more or less of earthy matter, and various salts; such as sulphate and phosphate of lime, sulphate of iron, and sometimes free acid, empyreumatic oil, and different gases. Klaproth has given the following analysis of peat from Mansfeld in Germany.

| | |
|---|---|
| Carbon, | 20.0 |
| Siliceous Sand, | 12.5 |
| Alumina, | 6.5 |
| Lime, | 4.0 |
| Sulphate of Lime, | 2.5 |
| Peroxide of iron, | 1 0 |
| Water charged with pyroligneous acid, | 12.0 |
| Empyreumatic oil, | 30.0 |
| Carbonic Acid, | 5.0 |
| Oxide of Carbon, | 12.5 |

*See Dumas' Chemie Applique aux Arts. Tome Premier p.* 592. "We might be tempted to believe," says Dumas, "from the above analysis, that peat differs little from wood: But the essays of Klaproth do not leave any doubt but that nearly all the combustible parts of peat are genuine ulmine; (geine) a result confirmed by the recent experiments of Braconnot on the peat of France."

Three specimens of the peat of Massachusetts, analyzed by the rules of Dr. Dana for soils, yielded the following results.

| No. | LOCALITY. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Silicates. |
|---|---|---|---|---|---|---|
| 1555 | Sunderland, | 26 00 | 59.60 | 4.48 | 0.72 | 9.20 |
| 6 | Hadley, | 34.00 | 60.00 | 1.36 | 0.24 | 4.40 |
| 1556 | Westborough. | 48 80 | 43.60 | 1.88 | 0.12 | 5.60 |

It ought perhaps to be mentioned, that I found it impossible to heat these specimens as high as 300° before proceeding to their analysis, because they would take fire below that temperature. I therefore heated them only to 200.°

As the black mud found in numerous swamps, which can hardly be called peat, differs from peat in its composition chiefly by the greater and uncertain amount of earthy matter which it contains, I did not consider it important to subject it to analysis. Enough has been given to show that the chief desideratum in Massachusetts, is not in the amount of vegetable nutriment which her swamps contain, but how best to bring it into a state proper to be taken up by the organs of plants. Undoubtedly Dr. Dana has pointed out the best method by the use of alkali: But when ashes cannot be procured, probably quicklime, mixed with barn yard manure and peat, or muck mud, may be a tolerable substitute: especially where any free acid exists in the peat that needs to be neutralized. In any case exposure to the alternations of heat and cold, dryness and moisture, is very important: except perhaps where the mud contains valuable soluble salts which would thus be washed away.

A substance very hostile to vegetation is sometimes found in our peat and mud swamps, viz. sulphate of iron, or copperas. I have met with it, however, in only one place in Massachusetts; and that was in Hubbardston on land of Willard Earl. The specimen sent me, however, contained only about 0.1 per cent. of sulphate of iron; yet it was sufficient to prevent the growth of any vegetable on the spot. But as this salt is soluble in water, most of it might have been extracted by rain from the specimen which I analyzed.

The antidote for sulphate of iron is lime. This not only destroys the copperas, but converts it into sulphate of lime, or gypsum, which is well known as one of the best fertilizers of a soil. But it is not probable that much of the soil of Massachusetts contains the sulphate of iron. It will be most likely to occur in the low lands, on a belt of country a few miles wide, extending north and south across Worcester County, on each side of the meridian of Hubbardston. On that belt the rocks and the soil often exhibit the color of iron rust, and this results from the decomposition of sulphuret of iron, whereby more or less of the sulphate of iron is produced. But as this is soluble in water, it will soon be either drained off or carried to the lowest spots.

### 2. *Geic Compound.* (*Apothemite.*)

On the farm of Col. Moulton, in the south-west part of Newbury, seven miles from Newburyport, occurs a peculiar substance, which, at first view, is pronounced to be a sort of peat; but on applying heat, it is found to be something quite different. Its color is a deep brown, hardly to be distinguished, when in mass, from black. When wet, it is soft and unctuous, and exhibits some degree of elasticity; when sun dried, it becomes quite hard, and receives a polish from hard substances Before the blow-pipe, the coloring matter disappears and a white enamel is formed. From an accurate and very satisfactory analysis which Dr. Dana has made of this substance, it appears, so far as I know, to be a new and undescribed compound. His analysis is as follows:

| | |
|---|---|
| Water, | 13.503 |
| Geine, | 19.625 |
| Silica, | 36.908 |
| Alumina, | 19.197 |
| Peroxide of Iron, | 8.826 |
| Sulphate of Lime, | 1.542 |
| Magnesia, | .402 |
| Specific Gravity, 2.08 | 100. |

"The earths and oxides," he remarks, "are such as we might expect from the decomposition of trap or greenstone: the geine, I presume, has been gradually deposited from the solution of vegetable matter in water. It has precipitated chiefly in combination with peroxide of iron, forming *pergeate of iron*. The sulphate of lime is doubtless derived from vegetable decomposition. It enters largely into the composition of the grasses; and all our waters, whether of ponds, rivers, or springs, contain, so far as I have examined, traces of sulphate of lime. The black coloring matter, or geine, is readily soluble in carbonated or caustic alkali: and keeping this fact in view, I think that, mixed with wood ashes, the above substanee will form a very valuable manure, particularly where the soil is light and sandy."

This geic compound at the locality above named, forms a layer from six to eight inches thick, and sometimes more, over several acres of a deep, basin-shaped cavity, which is nevertheless

-dry enough to plough. It did not seem to exert any fertilizing effect upon the soil in that place, but rather the reverse, though on this point I made no inquiries. But probably the geine is too strongly bound to the iron and alumina to be given up without the action of an alkali. Dr. Anthony Jones of Newburyport informs me, that he knows of two other places where this substance is found; one of which is on the north side of Merrimack river in Amesbury. Indeed there is every reason to believe, that it will be found in many places in Essex county, where sienite prevails, and it may therefore, become an object of no small interest in agriculture.

The astonishing power of this substance to absorb water, may be learnt from the fact, that while 100 grains of no soil absorbed, in 24 hours, quite seven grains, 100 grains of this compound absorbed 19.1 grains. This fact shows us that the absorbing power of soils depends much more upon the quantity of geine which they contain, than upon any other ingredient.

### *Use of this Substance as a Paint.*

This geic compound, with no other preparation than that of drying, has been employed as a paint, mixed with oil. It is said to answer a good purpose; and at Col. Moulton's I saw some wood-work covered with it, which appeared well. The color is so deep a brown that it passes very well for black.

It answers, also, as a water color, on paper. By simply grinding it in water and using it for a landscape, the color could hardly be distinguished from that called sepia. Through the kindness of John Tappan, Esq., of Boston, I obtained the following opinion respecting this substance, of a distinguished manufacturer of water colors in New York, to whom it was sent in a crude state, with no information respecting its nature or origin. By simply suspending it in water, it will be easy to obtain a much more delicate variety for the purpose of painting: and as it will probably be found of different shades of color at different localities, it may perhaps be an object to perform some experiments of this sort; for it may prove that it will be more valuable as a paint, than in Agriculture.

"The sample of color," says the manufacturer, "which appears to be a variety of lignite, might probably be of some use, as a deep brown color, for common purposes; but does not appear to have any extraordinary richness or body. It is not sufficiently *brown*, for either sepia or cologne earth, (or vandyke brown), and it is too brown to be sold for black. But if it could be sold quite low, it might come into use for a brown black, or deep brown."

For this geic compound, which appears to be well characterised, Dr. Dana has suggested the appropriate name, *Apothemite:* apotheme being the term applied by Berzelius to a depósite of geine, &c. in vegetable solutions.

## IV. SUBSTANCES YIELDING BOTH GEINE AND SALTS.

### 1. *Marsh Mud.*

I shall delay for a short time upon two other substances, abundant in the state, which may be of no small use in improving our soils, by affording both geine and salts.

Every intelligent farmer probably knows, that Marsh Mud forms an excellent manure; although I apprehend it is employed far less than its value demands. An intelligent farmer in Maryland states, that he "deems it more

valuable than barn-yard manure;" and that "it never failed in any application he had made of it." He also prefers it to marl, because "it is more accessible, its effects are quicker and much more can be done in the way of improvement for the same money." At the same time he confesses, that the permanent advantages of marl are much greater; and thinks that marl and marsh mud will both be improved by combination."* This last remark appears still more important, when we ascertain what it is that gives an agricultural value to this substance. The fact is, it sometimes contains a large quantity of geine, and sometimes but little, while the quantity of the salts of lime, soda, and magnesia, is rather large; so that sometimes a mixture of marl will be of service, and sometimes not. The following analysis of a few specimens of marsh mud, both in the ordinary way and by Dr. Dana's method, will show us, I think, what it is that constitutes its fertilizing power, and afford some useful hints as to its application.

### *Analysis in the dry way by Alkali.*

| No. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Oxide of Iron. | Lime. | Magnesia. | Salts soluble in Water. | Sulphuretted Hydrogen and Loss. |
|---|---|---|---|---|---|---|---|---|---|---|
| 135 | Newburyport, | 3.2 | 3.3 | 68.1 | 14.7 | 7.4 | 2.0 | 0.8 | 0.2 | 0.3 |
| 136 | Medford, | 9.5 | 12.5 | 50.95 | 14.9 | 8.15 | 1.1 | 0.2 | 0.6 | 2.1 |

### *Analysis by Dr. Dana's Method.*

| No. | LOCALITY. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Silicates. | Specific Gravity. |
|---|---|---|---|---|---|---|---|
| 134 | Cambridge, | 13.0 | 7.4 | 2.3 | 0.4 | 76.9 | 1.92 |
| 135 | Newburyport, | 1.5 | 0.1 | 3.0 | 0.5 | 95.1 | 2.52 |
| 136 | Medford. | 7.5 | 5.6 | 2.6 | 0.3 | 84.0 | 1.92 |

A substance so rich in geine, or salts of lime and soda, or in both, as the above analyses show, cannot but prove a fertilizer of the soil if spread upon it. If a soil be quite poor, those varieties of mud should probably be chosen that contain the most geine; and this can be judged of by their comparative lightness when dry; the lightest abounding most in organic matter. But if the soil already contain a good deal of inactive vegetable matter, the varieties that abound most in salts will probably be most efficacious; though an additional quantity of geine can do no harm, and may do much good. If marsh mud be applied at random, it is not strange that varieties of it, almost destitute of geine, should be sometimes put upon exhausted soil, and that no good effects should follow. Hence the necessity of some fixed principles to guide the farmer. And since Massachusetts contains so much sea board, and so much land near the coast that may be benefited by this substance, a correct mode of applying it is of great importance.

* Farmer's Register, July 1834; p. 93.

## 2. *Muck Sand.*

As this substance has never been proposed for use in agriculture, it will be necessary to state the circumstances that have led me to bring it forward in this place.

Ten or twelve years ago, Luther Root Esq., had occasion to dig a well in his garden in Sunderland, where he then resided. This was only eighty rods from Connecticut river, and the land there is alluvial to the depth of more than twenty feet. Near the bottom the excavation passed through a thick stratum of what is usually called quicksand, and which on being thrown out emitted a strong odor of sulphuretted hydrogen. It not being convenient to remove all this earth, it was spread upon a considerable part of the garden, which was a good soil and always well manured. He was warned against doing this, lest it should ruin his garden, and he thinks the quantity spread was not greater than a good coat of manure. The part thus covered was mostly planted with watermelons and other vines: and, instead of injuring the spot, it produced so great an increase of fertility as to astonish himself and his neighbors, and to lead them to search the banks of the river and low places for a similar substance. The good effects continued for two years, and afterwards declined, so that in a year or two the land thus treated was not better than the other parts of the garden.

Seventeen or eighteen years ago, Mr. Rufus Rice had occasion to dig a well on his farm in South Deerfield; and after passing through six feet from the surface, he struck upon what he describes as quicksand, though dry at the time he dug it, and probably mixed with clay. He represents the substance dug out when wet to be almost as much disposed to flow as water, and that it was very difficult so to wall up a well with stones that this sand would not pass through and fill it. He describes it also as giving out a strong odor, and a small quantity which he showed me, that had lain for fifteen years, still retained that odor, and appeared to be identical with the *Muck Sands* to be described in this Report. Wishing to remove the sand thus thrown from a well twenty-two feet deep, and having understood that the effect of a change of soil was good, he carted five loads, after it had lain exposed for a year, upon a piece of plowing, spreading it about as thick as a good coat of manure. This was in the autumn; and the next spring the whole piece was planted with Indian corn, after having been manured in the hill. But that part of the field, which had received the muck sand, soon began to show a much more thrifty growth than the other, and yielded a greater crop. From that time to the present, corn, oats and clover, have been the rotation of crops every three years, except that two crops of rye have been raised upon it, and whenever it was manured, all parts were spread over alike. And even up to the present time, the part on which the muck sand was spread, seventeen years ago, continues to show decidedly more fertility than the other part. I saw this difference in the autumn of 1837, in the crop of Indian corn then growing, and it was considerable.

A few rods from the spot where the well above noticed was dug, another had been excavated three years previously, to the depth of eighty feet, and a large quantity of the muck sand, with perhaps some clay, lay upon the surface; although the well itself had been filled by the caving of the sides. Mr. Rice carried from five to ten loads of this upon a spot of dry mowing, which had almost ceased to produce grass. It was spread about as thick as a good coat of manure, but with no mixture of manure, some time in June. On the first crop of grass that year it produced no effect, and there was not enough grass to be worth gathering. But the second crop was a very heavy one, and consisted mainly of clover which had previously disappeared. The next year the first crop was equally good, the second not so large, though better than middling. In subsequent years the good effects became less and less obvious: but they were visible at least ten years.

The facts communicated to me by Mr. Root (those respecting Mr. Rice's experiments I did

not learn till somewhat later) seemed to furnish a clue that might lead to results of considerable importance.

But the substance that produced such effects upon the soil had all disappeared from the surface, and could not be obtained from the wells. It occurred to me, however, that the same stratum must extend from Sunderland village to Connecticut river; and that its outcrop might be found there, as the banks are more than twenty feet high. A gentleman acquainted with the substance accompanied me thither; and we soon found a stratum of sand several feet thick, which he recognized at once as identical with that dug from the well. Having seen it in one place, I was able to trace it in others. I examined the banks of Connecticut river across the whole state; and wherever they are alluvial, I almost uniformly found this stratum from ten to twenty feet below the general surface. I traced it, also, in many places, in the banks of the Housatonic and Merrimac, the Deerfield and Westfield rivers, and indeed on almost every stream large enough to form much alluvial deposition. On the small streams its depth beneath the surface and its thickness are less. But its leading characters are alike, and somewhat peculiar: and as they made it easy for me to find the stratum, I think I can point them out so that others will be able to recognise it.

The specimens of this substance in the State Collection (Nos. 126, 127, 128, 129, 130, 131, 132, 133,) convey but an imperfect idea of its appearance in its native situation, where it is almost always very wet, and generally exhibits a slightly greenish tinge, though perhaps this results from its mechanical rather than its chemical characters. In the banks of our streams, this stratum is the first one from the surface that arrests the water in its descent into the earth: and hence water is seen oozing out from it in almost every place. It frequently lies immediately above a stratum of gravel. It is also remarkable for its yielding nature when wet: it being easy to run a pole several feet into it, and unless covered with turf, a man in walking over it will sink into it several inches. The cause of its arresting water in its descent, and also of the extreme mobility of its particles among themselves, is probably chiefly dependent upon the fineness of its texture, and the form of its particles, rather than upon its chemical composition. When an attempt is made to dig into it with a spade, or trowel, it conducts very much like soft suet. And yet its composition is decidedly sandy: and therefore I call it *muck sand*, although it generally goes by the name of *quick sand.*

Another important character is, that when fresh dug, this substance almost invariably gives out the odor of sulphuretted hydrogen: that is, an odor considerably resembling that of a gun barrel which has been fired repeatedly with gunpowder. Very frequently, also, there is seen oozing from it a reddish matter of the color of iron rust, and which indeed is the oxide of iron, proceeding probably from the decomposition of the sulphuret of iron, whereby the sulphuretted hydrogen is produced. I am inclined to believe that the odor of the sulphuretted hydrogen is so connected with its fertilizing properties, that I doubt whether any sand, not giving it out, will prove efficacious.

It should also be mentioned, that vegetable matter, even sometimes in the state of fibre, is generally present in the muck sand. Indeed, it seems to be the only stratum, which I have found deep in the earth, that contains much organic matter. In short, it does not differ, so far as I can ascertain, from the rich deposites of mud and vegetable matter, that are now often formed by our streams at high water, except that it has been for a long period in the earth, and thus many important chemical changes have taken place in it, and it has also been the recipient of all the soluble matter, which has percolated from the strata above, but which this stratum has arrested.

These remarks will I trust not only enable others to identify this substance, but will form also the groundwork of a theory that will explain its fertilizing power. This, however, will be better understood when I shall have presented analyses of several specimens by both the methods described in this report.

## *Analysis by Alkali.*

| No. | LOCALITY. | Water of Absorption. | Organic Matter. | Silica. | Alumina. | Oxide of Iron. | Lime. | Magnesia. | Salts soluble in Water. | Sulphuretted Hydrogen and Loss. |
|---|---|---|---|---|---|---|---|---|---|---|
| 126 | Sunderland, | 3.8 | 3.5 | 64.01 | 15.03 | 12.04 | 0.10 | 1.16 | 0.10 | 0 26 |
| 130 | Sheffield, | 2.0 | 2.0 | 70.68 | 11.61 | 10.10 | 0.80 | 1.63 | 0.15 | 1.03 |
| 132 | Amherst, | 4.0 | 5.0 | 64.34 | 13.5 | 12.00 | 0.06 | 0.90 | 0.20 | |
| 133 | Leominster, | 1.5 | 0.5 | 73.31 | 14.25 | 8.14 | 1.00 | | 0.10 | 1.2 |

I have been favored, also, with the following analysis of the muck sand (No. 129) from Hadley, by Dr. Dana.—100 grains, after ignition to drive off the water and organic matters, yielded,

| | |
|---|---|
| Silica, | 71.008 |
| Alumina, | 16.706 |
| Oxide of iron, | 6.202 |
| Lime, with some sulphate of lime, | 3.336 |
| Magnesia, | 1.552 |
| Traces of manganese and potassa, and loss, | 1.196 |
| | 100. |

## *Analysis by Dr. Dana's Method.*

| No. | LOCALITY. | Soluble Geine. | Insoluble Geine. | Sulphate of Lime. | Phosphate of Lime. | Granitic Sand. | Specific Gravity. | Gain of 100 grains in 24 h'rs after heating to 300°. | Propor'al Absorbing Power. |
|---|---|---|---|---|---|---|---|---|---|
| 126 | Sunderland, Ct. River, | 2.1 | 3.0 | 1.0 | 0.9 | 93.0 | 2.57 | 2.1 | 42 |
| 127 | Bradford, Merrimack River, | 0.8 | 3.1 | 0.6 | 0.7 | 94.8 | 2.48 | 1.8 | 36 |
| 128 | W. Springfield, Ct. River. | 4.1 | 0.2 | 3.0 | | 92.2 | 5.68 | 1.5 | |
| 129 | Hadley, Fort River, | 2.9 | 3.2 | 1.4 | 0.3 | 92.2 | 2.60 | 1.9 | 38 |
| 130 | Sheffield, Housatonic River, | 1.0 | 2.1 | 1.9 | 0.2 | 94.8 | 2.63 | 1.4 | 28 |
| 131 | Northfield, Ct. River, | 1.9 | 1.8 | 1.2 | 0.2 | 94.9 | 2.46 | 1.0 | 20 |
| 132 | Amherst, Fort River, | 6.3 | 0.0 | 1.2 | 0.7 | 91.8 | 2.39 | | |
| 133 | Leominster, | 0.4 | 2.3 | 1.0 | 0.5 | 95.8 | 2.68 | 0.4 | 8 |

The specific gravities given above show that in general the density of these muck sands is greater than that of most of our soils, as we might expect from the fact that they are very sandy. The two last columns show that their power of absorbing water is small; which result also we should expect for the same reason. The power of these muck sands to retain water, we should rather expect a priori might be considerable and of some service in agriculture. So far as the trials which I have made enable me to judge, they favor this presumption, though they do not indicate any remarkable retaining power. Thus, on the 20th. of January, 1838, 200 grains of the following soils and muck sands, with 100 grains of water added, were exposed three hours to the sun, from 11 to 2 o'clock, clear, and wind westerly; and they lost as follows:

| No. | | Loss. | No. | | Loss. |
|---|---|---|---|---|---|
| 3 | Alluvial Soil, | 69.7 grs. | 114 | Sienite Soil, | 54.4 grs. |
| 4 | do | 69.4 | 115 | do | 66.8 |
| 5 | do | 70.0 | 116 | do | 57.6 |
| 6 | do | 68.7 | 118 | do | 61.0 |
| 7 | do | 71.6 | 119 | do | 63.6 |
| 15 | Diluvial Argil. | 66.7 | 121 | Porphyry Soil, | 66.3 |
| 16 | do | 69.2 | 123 | Greenstone Soil, | 64.4 |
| 18 | do sandy, | 78.8 | 127 | Muck Sand, | 50.0 |
| 20 | do do | 67.7 | 129 | do | 50.1 |
| 23 | Sandstone Soil, | 68.0 | 130 | do | 51.4 |
| 24 | do | 56.6 | 131 | do | 56.2 |
| 26 | do | 70.1 | 132 | do | 47.1 |
| 27 | Graywacke Soil, | 70.1 | 134 | Marsh Mud, | 51.0 |
| 30 | do | 56.3 | 135 | do | 52.9 |
| 31 | do | 55.8 | 136 | do | 51.9 |

By referring to the general Table of experiments in June 1839, upon the power of soils to retain water, it will be seen that the few muck sands there given (No. 127, 128, 129, and 130) show a power rather greater than the average.

From the water in which some of the muck sand from Sunderland had been boiled, pure ammonia, as well as carbonate of ammonia and phosphate of soda, threw down slight precipitates. Hence I infer the existence of some soluble salt of magnesia, probably the sulphate. But in no other specimen did any such result follow the application of these tests. The proper tests, however, detected in them all sulphate of lime about in the same quantity as in most of the soils. Its amount may be seen in the table of analysis of the muck sands by alkali.

The preceding analyses appear to me to show that there is no single ingredient in these muck sands that will explain their fertilizing power. But there are several circumstances that probably conspire to such a result. Most of them contain a considerable amount of soluble geine, as well as of the sulphate and phosphate of lime; and I ought to remark in respect to some of them, that they were obtained in places which are exposed to the action of water a considerable part of the time, which may have abstracted a portion of the salts and the geine; as I took them from a few inches below the surface. This was the case with the specimens from Northfield, Bradford, and Sheffield. The others were obtained at a greater depth from the surface. That, for instance, from Amherst, which yielded so large a proportion of soluble geine, was taken from an excavation just made several feet deep. This circumstance should be kept in mind, if any of our farmers should think it best to make any trial of this substance. I hope they will take care to dig to a considerable depth to obtain it, although I should presume that two or three feet would be sufficient where the muck sand shows itself on the banks of streams; and yet the constant percolation of water from this stratum may carry off some of the fertilizing matters from I know not how great a horizontal distance.

It should not be forgotten that the muck sand is the first *water bearing stratum*, we meet in descending from the surface. Consequently if any soluble salts of potassa, soda, or other fertilizing substance, should be carried down by water, percolating through the more porous layers above, they would be found in this stratum, and very probably this circumstance is important in helping us to explain the salutary effect of muck sand upon vegetation.

In addition to the above circumstances, it ought to be borne in mind that this muck sand, on account of the minute division of its parts, is in the best possible state for enabling the roots of plants to act upon and absorb nutriment. Nor should it be forgotten, that in all cases when fresh dug, these sands give off the odor of sulphuretted hydrogen; which probably proceeds from the decomposition of sulphuret of iron, or some alkaline sulphuret, by the free sulphuric acid formed in the manner described by Dr. Dana, in giving a theory of the action of clays in agriculture. Very probably this sulphuret of iron may act an important part in fertilization by these muck sands; and hence it is desirable not to use any, certainly in early experiments, which does not emit the odor above named.

These considerations, with the facts that have been detailed, excite a hope that this muck sand may prove an article of no small value as a manure. The specimen from Leominister, however, given in the preceding table, should be noticed as deficient in some points, which, according to the preceding views, are important. It has little if any soluble geine, and the salts are in small proportion. That specimen was received from Mr. Sewall Richardson, who says that it was taken seven feet below the surface, and that it has been dug three years, and exposed to atmospheric agencies. It may, therefore, have lost some of its fertilizing properties. Yet he says, "for the last four years I have applied it as manure on dry land, and find that it produces a good effect. One quart, applied to a hill of potatoes before hoeing, seems to prevent the effects of drought on the driest of our plains, and makes them yield potatoes equal to the best of our land." He says, also, that "it has as much effect on the skin, when first dug and dryed, by handling it, as lime, or ashes." It was in consequence of these statements that I subjected this specimen to analysis; although it bears but little resemblance to the muck sands in general.

Since my attention was first called to this substance by the facts that have been detailed, I

have heard so many statements of the striking effects produced upon vegetation by matters dug out of wells and other excavations, that I feel more and more convinced here is a source of fertilization for soils that has been hitherto overlooked, and which may prove of important benefit. I do not give these facts in detail, because I cannot identify the substances used with muck sand. Indeed, I am not without suspicion that my description of muck sand must be considerably enlarged to embrace all the subterranean deposites which act in a similar manner. Perhaps neither its mechanical nor chemical constitution is of any great importance, and that any subterranean deposite may be found to possess fertilizing properties, which has become the reservoir of the soluble matters that have penetrated from the surface.

When one has proceeded so far towards the extemity of Cape Cod, as to judge from the landscape around him that he has got almost beyond the region of vegetation, his attention is suddenly arrested by one or two excellent farms in the northern part of Truro, belonging to the Mr. Small: which having passed, he sees scarcely anything more of cultivation to the end of the Cape. On examination of the cliffs near Mr. Small's on the northeastern or Atlantic shore, he will find strata of blue or greenish clay. This clay appears to me to be only a variety of the muck sand that has been described; or at least, where it is washed down by the rains, it becomes muck sand: And this fact explains the fertility of this oasis. Nor can there be any doubt, but if this clay bank could be mixed with the sand in the surrounding region, it would form a soil of superior character. At present, however, the cliff is of difficult access, having long been exposed to the buffetings of the wide Atlantic. But the clay extends as a subsoil over the whole of the farms above described: and by digging a few feet, it might be obtained. The time will come, I doubt not, when this clay bank will be thus employed.

The wide diffusion of this muck sand in the state, makes me more desirous of having it tested. I have already remarked that it may be found on the banks of all our streams, which have deposited alluvium. And I doubt not it may be found in most swamps; especially those that are underlaid by clay. From the banks of rivers it might be carted at a season of the year when the water is low, since the stratum usually lies but little above low water mark: and from other places excavated on purpose, it might be obtained at almost any season. Should only a small part of the fertilizing effect result from its use generally, which the facts detailed would lead us to expect, I should still feel amply repaid for my labor devoted to the subject.

Beneath the vegetable matter in most of our swamps, there is a fine sand, quite analagous in appearance to the muck sand that has been described: and from some facts that have come to my knowledge, I suspect that this possesses, in part, at least, the fertilizing character of the muck sand. It probably contains some soluble geine and salts of lime, and sometimes gives off the odor of sulphuretted hydrogen; though perhaps this may result from decayed vegetables, as these sometimes emit an odor resembling that gas. I apprehend that this sand may be found often to possess enough of a fertilizing character to be profitably employed upon land. Benjamin Hobart Esq., of Abington, informs me, that in consequence of my remarks upon muck sand in my Report of 1838, he was led to try what he supposed to be that substance, obtained from beneath a mud swamp. He spread about as much of it as a good dressing of manure upon 10 or 12 acres of grass, and the effect in 1839 was very decided in increasing the amount of hay. I am unable, however, to give further details.

### 3. *Deposits from Rivers.*

Dr. S. L. Dana has furnished me with an extremely interesting communication on this subject, which I shall give in his own words: and which needs no recommendation of mine to engage the attention of the man of science, as well as the practical agriculturist.

*Lowell, Dec.* 18, 1839.

DEAR SIR:—I send you my remarks on the matter, suspended, or dissolved, in the waters of Merrimack river. This matter is interesting both to the geologist, and to the agriculturist. To the former as a question in geological dynamics, and to the latter, as the source of the fertilizing power of overflowing streams.—I am indebted to the assistance of Mr. James B. Francis, Civil Engineer, attached to the Locks and Canals in this place, for the computation of the quantity of water flowing in Merrimack river. The daily register of the height of the river, kept under his inspection, added to his minute and accurate measurement of the daily volume of water, has enabled us to approximate the actual amount of effect, due to a portion of one of the causes of geological change, in present operation, with a degree of certainty, which, if not entirely satisfactory, is more accurate, than has heretofore been attempted. Ordinarily the Merrimack river is clear and transparent, having a slight yellow brown tinge, by transmuted light. Great rains produce turbidness. The water becomes clay colored. During these periods, I have daily taken out 20 gallons of river water, and after 24, to 48 hours repose, in a vessel about 18 inches deep, the water was decanted, the sediment collected on a filter, dried at 300° F. and weighed. From these data, and his own measurement of the quantity of water, Mr. Francis has calculated the following table, showing the amount of matter borne seaward, by Merrimack river in 1838, and during an unusually high fresh in 1839.

| Date | | No. of Days. | Quantity of Water in cubic feet. | Grains of suspended matter in 1 cubic foot. | Total suspended matter in pounds avoirdupois. |
|---|---|---|---|---|---|
| From | to | | | | |
| 1838, May 5. | May 9. | 5 | 9.630.316.800 | 3.583 | 4.929.346. |
| " 26. | " 29. | 4 | 5.738.428.800 | 19.531 | 16.011.036. |
| June 5. | June 9. | 5 | 5.150.562.400 | 3.366 | 2.475.256. |
| Nov. 9. | Nov. 12. | 4 | 13.105.843.200 | 25.808 | 48.319.371. |
| " 13. | " 17. | 5 | 8.690.889.600 | .112 | 139.054. |
| Total | | 23 | 42.316.040.800 | | 71.874.063 |
| 1839 Jan. 28. | | 1 | 4.685.817.600 | 30.483 | 20.405.397 |
| " 29. | | 1 | 3.633.526.400 | 22.815 | 11.855.023 |
| " 30. | | 1 | 1.818.115.200 | 12.006 | 3.118.327 |
| 31. | | 1 | 794.966.400 | 4.226 | 479.932 |
| " Feb. 1. | | 1 | 529.977.600 | 1.481 | 112.128 |
| Total. | | 5 | 11.466.403.200 | | 35.970.807 |

Leaving out, adds Mr. Francis, the 23 days given above, I find the average flow of the river for the remainder of 1838, about 6000 cubic feet per second—giving a total discharge for 342 days of 177, 282, 800, 000 : cubic feet.

The question, whether the year 1838 is an average can only be determined by continued observation. I am still directing my attention to this point. I incline to the opinion

that 1838, is a fair average year. It is seen from the table that during the great freshet of Jan. 7, 1839, nearly one half as much matter was borne downwards in 5 days, as during the whole year of 1838. This was the highest freshet observed for the last 6 years. The table above gives the actual amount only, which would be deposited by a few days repose. This amount is interesting only to the agriculturist, whose lands are fortunately irrigated by these periodical overflows. To estimate the actual geological effects, we must add to the above amount a finer deposite which longer repose precipitates from the waters of a freshet, and the matter chemically solvent both during a freshet and ordinarily, and also the amount of matter ordinarily suspended. This last quantity is 0.100 of a grain per cubic foot of water. After the clay colored matter has settled, a finer white deposit occurs in a few days. It is so fine as to pass through filtering paper. It gives to the water a slight milky look viewed in a tube of 3 inches diameter. It is long subsiding, and gradually collects in fine white flakes, which precipitate, forming a skinny lining on the bottom of the vessel. This membraneous lining by some months exposure to air, becomes dark olive green colored. It consists chiefly of silica with an organic acid. It ought not all truly to be called suspended matter—though for the present purpose I so estimate it. The skinny deposit, which occurs, *lichen* like on all substances long time under the river water seems of similar nature.—I may remark here, that the clay colored deposit occurs in substances in the water, whatever their position, slanting, upright or flat. Its slimy nature causes it to adhere whatever the position, and when collected from the bottom of a tub it may often be rolled off in a continuous sheet, like tough wet paper.

The water of the freshet of 1839, decanted from the sediment deposited in 48 hours, was allowed to repose one month: it became perfectly clear,—though slightly milky at first, and the amount of the fine white flocculent precipitate, which now formed a skin, was in one pint 0.3857 grain or per cubic foot 23.0015 grains. No more deposit occurring after 7 days repose, the water was evaporated to dryness. During this operation brilliant scales began to form and a filmy white mass, with a brown tinge remained, weighing in one pint of water 0.6172 grain, or per cubic foot, 36.776 grains. This amount is less than that ordinarly in solution; for by long exposure, a portion of the chemically solved matter is decomposed, or forming new combinations was precipitated. The amount of matter ordinarily held in solution in the river water is 0.82 grain per pint, or 48.86 grains per cubic foot. If now we add to the matter suspended in the water in

| | |
|---|---|
| the 23 days by the above table, | 71.874.063 pounds. |
| The finer deposite in 23 days, | 139.280.225 pounds. |
| The matter chemically solved in 23 days, | 221.853.831 pounds. |
| Matter ordinarily suspended in 342 days, | 2.532.611 pounds. |
| Matter chemically solved in 342 days, | 1.242.803.080 pounds. |
| We get the total for year 1838, | 1.678.343.810 pounds. |

The mind cannot conceive this amount. We may form a more precise idea of its extent by supposing the whole to be anthracite coal. At the present rate of coal consumption in the Merrimack Print works, 5000 tons per annum,—the above would then last 167 years.

## *Chemical Constitution of the Suspended Matter.*

I collected in 1837 a quantity of this substance, deposited on the rocks at Pawtucket falls in Lowell. This was analyzed by drying at 300° F. then calcining to destroy organic matter, fusing with alkali, and separating the constituents in the usual way. I add the analysis of a similar deposit, from Connecticut river, collected in 1837 from the rocks just above the bridge between Greenfield and Montague. In both, traces of mosses, vegetating were evident to the eye.

| | Merrimack River. | Connecticut River. |
|---|---|---|
| Organic matter, geine, | 2.500 | 2.640 |
| Silica, | 77.530 | 77.397 |
| Alumina, | 8.650 | 8.325 |
| Oxide of Iron, | 9.500 | 8.848 |
| Lime, | .535 | .767 |
| Magnesia, | .103 | |
| Sulph. acid, Phosphoric acid, | | |
| Traces of potash and loss, | 1.182 | 2.023 |
| | 100. | 100. |

The finer deposit occurring after a month's repose, gave a constitution similar to the above: and the water evaporated, after all mechanically suspended matter had subsided—gave, in one pint, 0.6172 grain, composed as follows:—

| | |
|---|---|
| Organic matter, | .3086 |
| Lime, with some Sulphate of Lime, | .1928 |
| Silica, | .1155 |
| Loss, | . 003 |
| | 0.6172. |

The organic matter exists chiefly under those forms of geine called crenic and apocrenic acids. It readily solves in water, with a brown color; decomposes some metallic salts, and combines with lime and moist hydrate of alumina. Its acid action is the source of the rapid solution of lead in Merrimack water. Crenate of iron, and alumina, is deposited rapidly on iron tanks and pipes exposed to the constant running of the river water. I have seen this compound deposited 1-2 inch thick in two years in an iron tank, on its upright sides; and mamillary concretions, like large almonds, covering large patches of a cast iron pipe, which had been in use a few years only. These concretions will doubtless in time accumulate, and finally obstruct the passage of water though iron pipes used for its conduit.

The constitution of the deposit, collected on the rocks of the river, is analogous to your "*muck sand.*" The organic matter, which is geine, is the source of the vegetating power, which the sand gives to seeds. In many places, where the alluvial deposit forming the basin of Lowell has been cut through, layers of "*muck sand,*" from 2 inches to several feet in thickness have been exposed. They are separated by strata of coarse sand and gravel. When this section has been sometime exposed to air, the "*muck sand,*" can be distinguished at a great distance, by green bands, a color derived from the infinity of small plants vegetating and luxuriantly growing in the stratum. This is certainly a very strong proof of the agency of geine, if not of its actual necessity to growing plants. Whether we believe with Fuchs that geine, which he calls humus, is among the original and earliest formations, or with others, that it is of later origin, arising from organic decomposition, it is evident, that being so abundantly diffused in river deposits, which ultimately become sea deposits, it is the source of the carbon, and also of the ammonia, which late experiments have detected in primitive rocks. In the great series of geological changes, these sedimentary deposits, now taking place, will doubtless arise in new forms, in mica, and clay slate, perhaps of rocks of crystalline character. But let us leave speculation and attend to the

## *Agricultural Value of River Deposits.*

All experience teaches the fertility of soils periodically overflowed by the turbid waters of rivers. Perhaps from the similarity of chemical constitution of the deposited matter, with " muck

sand," the reason of its fertilizing power will be obvious to the readers of your report on that substance. We can refer the fertility given by the overflowing freshets only to the geine, salts of lime, and beautifully fine state of the silicates which make up the bulk of the deposit. The silicates being so exquisitely divided are readily decomposed by the action of the air, the carbonic acid eliminates potash and soda from the silicates, just as the same action decomposes the silicates of alkali in spent ashes, peat ashes, and greensand. Indeed I have no doubt, that the green sand, which you sent me, had lost its potash from this very cause. Our granite, particularly, that most abundant in felspar, should, if finely pulverized, act like green sand. The river deposits, containing silicates of alkali finely levigated, and exposed to the carbonic acid of the air, and the electro-chemical agency of growing plants, are rapidly decomposed. The alkali is evolved and solves the geine and geates, which make up no small portion of the deposit. I have subjected several portions of these deposits, collected at different times, to Agricultural analysis. The results are shown in the following table.

| | Sol. Geine. | Insol. Geine. | Sulph. Lime. | Phos. Lime. | Silicates. | |
|---|---|---|---|---|---|---|
| Connecticut River. off rocks. | 2.30 | 1.70 | .64 | .46 | 94.90 | All give up to water Sulphate and geate of Lime. |
| Merrimack River, Spring of 1837. off Rocks. | 2.50 | 1.10 | .90 | .60 | 94.90 | |
| " Fall of 1837. off Rocks. | 2.06 | 1.86 | .74 | .90 | 94.44 | |
| Deposit from Freshet of January, 1839. | 5.40 | 6.50 | 2.34 | 1.20 | 84.56 | Oxide Iron, Alumina, Magnesia, Sulph. and Phos. acids in the soluble geine are 2.34 |
| Deposit, July, 1839. | 8.80 | 6.30 | 3.10 | .60 | 81.20 | Oxide Iron, Alumina, Magnesia, Sulph. and Phos. acids in insoluble Geine, 1.50. |

The true agricultural value is shown by the deposit from the freshets of January and July, the others being coarser sediments, that is more sandy. With great respect,

SAMUEL L. DANA.

## V. AMENDMENT OF SOILS.

It may perhaps be expected that I should, before I close the subject of soils, endeavor to show how the defects of the different geological varieties of soil in Massachusetts may be remedied, in addition to the more general views, that have been presented on the subject. But in most cases I doubt whether chemistry or geology can add much to what the farmer has already learnt from experience; and therefore the subject, as I conceive, hardly falls within my department. I shall, however, add a few remarks respecting the amendment of a sandy soil; since a large part of four counties in the state, viz. Plymouth, Barnstable, Dukes, and Nantucket, are on this account at present regarded as sterile beyond reclamation.

It is indeed true, that lands so barren as those above referred to, can be brought into a fertile condition only with great labor and expence. It is however, similar lands on which green sand in New Jersey and other states

has exerted a remarkable transforming influence; and should any of the green sand of Massachusetts prove serviceable, its use would probably be the most economical mode of commencing the work of fertilization. But a surer plan is to follow the methods adopted with so great success in such a country as Netherlands; where the most barren sands have been extensively converted into fruitful fields. Where such a soil is underlaid by clay, or loam, even if it lie at the depth of several feet, an obvious preliminary is to bring a large quantity of the subsoil to the surface; and then to introduce into the mixture a sufficiency of geine. But even where no such subsoil exists, the case is not a hopeless one. The first step is to plant the surface thickly with some plant that will grow upon it; and as this decays, it will form geine for future use. Ere many years, enough nutriment will be collected to form a soil, in which useful plants will grow: and when once brought into this state, it is, taking all things into the account, one of the best of soils. The Belgic farmers commence with broom, pines, &c. In Massachusetts beach grass (*Arundo arenaria.*) is usually employed to fix the sand: but I doubt whether this is very well adapted to form a soil; since it decays so little. I noticed that in the old fields upon Cape Cod, which had been cultivated until the geine was nearly exhausted, that large patches of the *Hudsonia ericoides*, or *false heath plant*, and of *H. tomentosa*, or *poverty grass*, were frequent. These form a thick mat upon the soil, and cannot but collect some vegetable and animal nutriment. May they not be made serviceable in the way that has been described.

When I visited Provincetown nine or ten years ago, scarcely a square rod of land was attempted to be cultivated in the whole town. But on a recent visit, I perceived several gardens of considerable extent; containing a good crop of vegetables, and of excellent quality. Mr. Lathrop in particular, the enterprising proprietor of the hotel there, has prepared an excellent garden, chiefly by manure and the mixture of the salts of lime and magnesia, which are obtained in great abundance from the extensive salt works in that place: and which are just coming into use on the Cape as a manure, and will undoubtedly prove serviceable if used only in small quantities. Mr. Lathrop thinks that garden vegetables may be raised there a fortnight earlier than in the region around Boston; and that hence it may be an object to raise them for Boston market. This hint may be worthy the consideration of the farmers on other parts of the Cape. Mr L. also showed me a swamp of considerable extent, probably a peat swamp, which he proposes to convert into arable land, by bringing over it a quantity of sand from the adjacent hills. I hope this experiment will be tried, not only there, but in other parts of the sandy region of Massachusetts, where such swamps are common. For although expensive at first, land thus formed must become exceedingly productive and valuable.

But the most striking example which I have met with showing how productive the most barren soil may become, was pointed out to me by James Small Esq. of Truro on Cape Cod. In passing down the Cape, long before

one reaches his farm, most of the country appears excessively and hopelessly barren. His farm, however, is based upon blue clay, and forms a fruitful oasis amid the sandy waste. But between that spot and the end of the Cape, little meets the eye, out of the salt marshes, but white drifted sand, save here and there a small patch of beach grass, or pine shrubs, or poverty grass. Yet three miles beyond his house, Mr. Small took me to a field of several acres, where the soil appeared of a dark color and abounded in fragments of shells, particularly the round clam, or *quohog*. So productive was this soil, that 50 bushels of Indian corn had been raised upon an acre without manure! The following analysis shows us at once the secret of this fertility.

Reckoning the fragments of shells as carbonate of lime, we have in 100 parts:

| | |
|---|---|
| Carbonate and Sulphate of Lime, | 21.30 |
| Phosphate of Lime, | 0.35 |
| Soluble Geine, | 3.75 |
| Insoluble do | 1.50 |
| Silicates, | 73.10 |
| | 100.00 |

After the salts of lime and the geine were separated, the residue consisted of nothing but the common white sand of Cape Cod. This geine and these salts, therefore, are all that is necessary to convert other sandy fields on this Cape into fertile spots.

I find these broken shells to be somewhat frequent on the Cape; and the general impression is, that they were brought into their present situation by the Indians, that the animals might be extracted for food. But their great extent leads me rather to suspect that such spots were once the residence of these animals, when beneath the sea: or rather, that they were once the shores of the ocean, and that the waves drifted the shells thither.

### *Concluding Remarks upon Soils.*

I might proceed to discuss numerous other points respecting the chemical and geological character of soils and cultivation. But really, I do not feel prepared to throw any new light upon them; and will not therefore occupy space and time with detailing what is already described in various authors, such as Davy and Chaptal. The time and labor which I have already devoted to this subject, are more than I should have felt justified in bestow-

ing, were it not of the first importance. Those only who are practically familiar with analytical investigations, can correctly judge how much time and labor it has cost me to obtain even the imperfect results that have been given. In analysis a result which is expressed by a single figure, often costs days of careful labor to obtain.

It will be seen that a considerable part of what I have presented on this subject (and the same remark will apply to much that follows on economical geology,) consists of suggestions. The many new views, which through the aid of Dr. Dana I have brought forward, and the new substances to which I have directed the attention, rendered such a course necessary: since it was impossible for me to prosecute the requisite experiments for testing the truth of my convictions. Of course, others who have an opportunity to make such experiments, will place so much confidence in my suggestions as the reasons offered to sustain them, will in their opinion justify. Should any of these suggestions be carried out into practice and produce valuable results, my object will be attained, even though they should require such modification, that the original author shall be forgotten and unnoticed.

I confess myself influenced in these researches by an ambition to point out some of the means, whereby two or more blades of grass, or ears of corn, may be made to grow where one grows now in Massachusetts. And this I sincerely believe to be an attainable object. More and more thoroughly am I convinced, that it needs only patient industry—such as has ever been the glory of New England—and an intelligent and judicious application of our internal resources, to convert five sixths of the surface in Massachusetts into fertile fields. The idea that a large part of our soil is absolutely unfit for cultivation, and incapable of improvement, which has discouraged so many of our young men, and driven them away from their paternal homes, is contradicted at every step of a fair investigation of the subject. As I have approached one of our beautiful villages, and seen all around it such prolific crops, I have frequently enquired why such a difference exists between the fertility there, and the wide region over which I have been passing since I left the last village? For in the natural character of the soil I could perceive no essential difference. The conclusion would be, that cultivation has made all the difference. And yet, in that village are probably many young men who feel as if all the valuable land around them were taken up, and that they must seek their fortunes in some distant and more fertile region. It is true that our soil will yield to nothing but persevering industry and skill. But the habits of diligence and endurance which will be acquired in subduing it, are of far more value to the possessor, both for the promotion of his fortune and his happiness, than the richest manor that yields almost spontaneously. The very object of Providence apparently in giving us a soil by nature comparatively sterile, yet capable by cultivation of yielding an abundance, was to call into exercise that

industry and energy, without which man becomes a mere drone, or the miserable slave of indolence and the low appetites.

I do not doubt but the Government and every intelligent reflecting citizen will feel the vast importance of energetic efforts to improve our soils so that they may sustain a larger population. This is the only way to check the tide of emigration that sets so strongly to the great West. For if our sons can be made to see the soil of New England doubling its increase, as I verily believe they might in one or two decades of years, the rich alluvia and prairies of the West will not be able to draw them away from the graves of their fathers; especially if they learn that those fertile regions will at length become exhausted of their geine and salts, and then will probably require as much labor to cultivate them as the soils of Massachusetts.

Some, however, may contend, that it is more important to transfer the New England character to the unsettled West, than to multiply our numbers and wealth at home. But the history of the world leads us to fear, that New England character cannot long be preserved except upon New England soil; or upon a soil that requires equal industry for its cultivation. Place New England men where the earth yields spontaneously, and the locks of their strength will soon be shorn. If we look over the map of the world, and the history of the past, we shall find as a general fact, that the brightest exhibitions of human character have been made, in regions where nature has done less, but art and industry more. If, therefore, we wish to increase the moral power of New England, it must be done by improving her soil, and increasing her resources and her population. If these views are correct, which I acknowledge do not fall in with the prevailing notions, they furnish a new stimulus for vigorous effort in the improvement of our soils.*

### *Note on the Nature of Geine.*

Having transmitted a proof sheet to Dr. Dana, of my remarks on the nature of geine, with Dr. Jackson's method of analysis, he has been led to send me his views on these subjects more fully than ever before. His letter contains so fair and masterly a defence of his views concerning the nature of geine, that I am unwilling to withhold it; especially as it seems I have misapprehended some of his opinions on that subject. And since Dr. Jackson seeks only truth, like every man of genuine science, he will not, I trust, object to so candid an examination of his opinions.

* This may be the best place to mention, that the first column of the Table showing the power of soils to absorb oxygen on page 63, should have placed over it the words, *Per Cent*: the second column, the words, *Cubic Inches*: and the third column, the word, *Grains*.

*Lowell, June* 22. 1840.

DEAR SIR:—You know I have for some time meditated a new analysis of geine. My engagements have prevented my undertaking this point, in season for your report, and I very much doubt whether such an analysis as I can ever execute, would throw any new light on its constitution. Perhaps in the present state of the opinions respecting its nature, my analysis would be considered ex parte evidence. I am satisfied with the results already obtained by others. From the days of Vauquelin, who first noticed ulmin, to the present time, this substance has been investigated by the most distinguished chemists, under the name of ulmin, or humus, or geine. These are convertible terms, they mean one and the same thing. Its atomic constitution was partially settled by Sprengel, and more fully by Boullay Jr. The discrepencies in the results, led Berzelius to remark, that the whole subject required a new investigation, though Dumas expresses his confidence in the results of Boullay. His statements have since been verified by Malagutti. Thompson, in his Organic chemistry, refers to Malagutti's paper, as published in *Journ de Pharm. xxi.* 455. and Dumas, in his 5th. Vol. refers to Malaguti's *observations inedites.*

Malagutti has obtained ulmic acid in distinct crystals. By boiling these in weak acids, a black substance is deposited, which he calls ulmin, identical in its composition with the acid. Once and for all, I consider, ulmin, humus, geine, ulmic, humic and geic acid, one identical substance; whether neutral or acid its constitution, ever one and the same, subject to the great law of organic chemistry, that proximate compounds act as simple elements.

Boullay's analysis of geate of copper, on which he placed most reliance, is the following:—

| | |
|---|---|
| Geine, | 89.5 |
| Oxide of Copper, | 10.5 |
| | 100. |

Malagutti's result agrees with this, more nearly than is usual in minute analysis, and is as follows:—

| | |
|---|---|
| Geine, | 89.2 |
| Oxide of Copper, | 10.8 |
| | 100. |

Deducing from these analyses the atomic weight, we get from Boullay, 42.61
from Malagutti, 41.29
83.90 the mean 41.95.

The result of the analysis of geic acid, by oxide of copper is by

| | Boullay, | Malagutti, |
|---|---|---|
| Oxygen, | 56.7 | 57.48 |
| Hydrogen, | 4.81 | 4.76 |
| Carbon | 38.49 | 37.36 |

Deducing from these the atomic constitution of geine, we get from Boullay, with whose ratios Malagutti agrees,

| | | | |
|---|---|---|---|
| Oxygen, | 16. | atoms | = 16. |
| Hydrogen, | 16. | " | = 2. |
| Carbon, | 32. | " | = 24. |
| | 64. | | 42. atomic weight |

Now the mean of the result, 41.95, from the analysis of geate of copper given above, differs 00.05 from the theoretical result. We may safely take, therefore, 42. as the atomic number of geine.

A substance found by different observers so identical in composition, by actual analysis, whose theoretical confirms its analytical constitution, which forms definite compounds, and whose history and properties are better understood than a large proportion of the objects in organic chemisty, may well be considered a definite chemical compound. That it is so, is believed by all chemists, except Raspail, whose principles would equally reduce the larger portion of organic substances, to carbon and water; and Dr. C. T Jackson, who reduces geine into a mixture of crenic and apocrenic acids. Others have admitted these acids in combination with geine, in soils. Berzelius their discoverer, and to whom we are indebted for all that is known of their history, years ago said, that crenic and apocrenic acids existed in soils, in small quantity; and moreover states, that these acids are among the general products of putrefaction. The doctrine then, that they are found in soils, is not the doctrine of yesterday nor of to day—it is no new thing; but the doctrine that geine is a mixture of these acids, that geine has no independent existence, is new; and coming from a source, commanding our respect, requires a careful consideration. The various opinions which have been formed on the subject of geine, owe their existence in part, to the varied means which produce this substance. It comes from organic matter, by putrefaction, by the action of acids and of alkalies, caustic or carbonated, by the action of alkaline earths, by alumina, by metallic oxides, acting on organic matter, especially when assisted by heat, and as a general law, we may say that all substances, oxidating, and gently acting on organic matter, produce geine. It is produced by fire, by heating or roasting organic matter, and hence its abundance in soot, in crude pyroligenous acid, in charcoal, and baked wood. It is found in carburet of iron; and cast iron, treated with acids, leaves an insoluble residue, having the properties of geine. Of all the agents, which thus change organic matter into geine, the action of the alkalies and of the alkaline earths is most powerful: next to them ranks alumina, which is little, if at all inferior to lime, when assisted by growing plants. It is the decomposition of the aluminous silicate, by living plants, which lets loose the alumina, to convert insoluble into soluble geine. But to return, the mode of acting here is in many cases purely "*catalytic*," the action of presence,—the same elements re-arranged, a new order takes place,—while in other cases, a part of the original compound is removed—new substances are produced. In whatever way we may produce the proximate principle geine, whose definite constitution we see has been so well determined, it is not at all probable, that it proceeds, *per saltum*, from organization to its atomic constitution. There exist, doubtless, intermediate states, other compounds, which chemistry has already, or will hereafter detect; forms of geine so to speak.—In this class, I include crenic and apocrenic acid. Nor can we determine whether these arise from a catalytic change in geine, or whether they are formed first, and then unite to produce that definite compound. But the properties and actions are so very distinct from those of geine, that the last cannot be owing to a mere mixture of thetwo first. From the small quantity in which they accompany geine in soils, it is probable that they derive their origin from a change in the elements of that substance; and if ever geine, has been *wholly* reduced to crenic and apocrenic acid, I think it is no difficult matter, to show how this result has been produced by the agent employed, and by the manipulation. Cases analagous are familiar to all chemists, and the very ease with which crenic passes into apocrenic acid, may help our conceptions of the possibility of a mere new arrangement of the elements of geine,—an arrangement producing two well defined acids, being considered as the separation of those which previously were only mechanically mixed.—As evidence of the evanescent nature of crenic acid, it is well established, that its solution in water, by simple exposure to air, becomes apocrenic acid: hence it name: its existence, as Berzelius says, depends on crenic acid, just as *apo*-theme, depends for its existence on a solution of organic extract in water. Without crenic there can be no apocrenic acid. These acids have been separated. Their insulation is one of the most difficult of chemical operations, requiring not one, but several solutions and separations by sulphureted hydrogen before we can estimate their quantity, or be assured if their purity. Separated, their characters are as follows:—Both resemble vegetable extract:

| *Crenic acid.* | *Apocrenic Acid.* |
|---|---|
| Color yellow, | Brown, |
| Transparent, | |
| Amorphous, | Amorphous, |
| Taste acid, then astringent | Astringent, |
| *Excessively* soluble in water and | Slightly soluble in water. |
| " " alcohol | Slowly soluble in pure alcohol |
| | Solution in water, precipitates by Sal. ammoniac in flocks. |

| *Crenates.* | *Apocrenates.* |
|---|---|
| Of alkalies, like yellow extracts, and very soluble in water, and weak alcohol. | Of alkalies, black friable masses; in water a dark soluble brown color. |
| Of lime, neutral, soluble in water, subsalt, insoluble. | |
| Of magnesia, easily soluble in water. | Of alkaline earths, solve in water, yellow colour. The subsalts quite insoluble. |
| Of alumina, neutral insoluble in water: supersalt, soluble. | Of alumina, neutral, insoluble: supersalt, soluble in water. |
| Of iron, soluble in water. | Of iron, protoxide, soluble in water: peroxide, insoluble in water. |

From the statement I have already made of the elements which enter into soluble geine, it will be seen that a small part only of soils exist, as a geic salt. The phosphoric acid I have ennumerated among these elements, confining the term "soluble geine" in that case to all which an alkali dissolved. The phosphoric acids proceeds from a partial decomposition of phosphate of lime, or subphosphate of alumina. It is not an element of geine. The iron and alumina are dissolved as salts of geine. We conclude that the greater part of the geine of soils exists uncombined. If this substance, as it exists in soils, is only a mixture of crenic and apocrenic acids, then, from the established properties of these acids and their salts, this result must follow. *The soluble organic matter of soils ought to be completely solved by water and alcohol.* No other agents are required to detect not only the existence, but the total amount of these acids, to determine in fact the amount of soluble geine. Simply boiling the soil in water should extract all the crenic acid. "It is excessively soluble in water," says Berzelius—so soluble, that the water of the Porla well, the source whence this acid was first obtained, is colored brown by it. Pure alcohol, will then dissolve all the apocrenic acid; and we may thus at once ascertain the amount of these acids. Admitting the properties of crenic and apocrenic acid, I do not see, how we can escape this conclusion. Nor will it alter the case, if it be said that the acids are combined with the bases of earths and oxides. We still are driven to the same conclusion. Now this is a result, which I presume the propounder of this doctrine of the mixed nature of geine, will not admit. He knows how very trifling is the proportion of organic matter, or its salts which yield to alcohol, or to water. I do not mean to deny that this little is crenic or apocrenic acids or their salts. Nor will the advocates of the doctrine, deny, that all the crenic acid, will, by exposure to air, pass into apocrenic acid. If then, geine be a mixture of acids, and is insoluble in the agents which act easily on these acids while separate, we may reasonably conclude that the elements of these acids, have arranged themselves anew, entered into a *true chemical combination*, to form geine, a definite proximate principle, whose separate, independent existence, whose properties, combinations, and uses, are as well established as any facts in chemistry.

Finding then, that the action of water and alcohol on the geïne of soils is wholly different from that which ought to ensue, if it is a mixture of crenic and apocrenic acids, other agents have been employed to effect their separation. Now these agents, are precisely those, which we have enumerated above, as having the power to alter the arrangement of the elements of organic matter, or of geine; developing either acid properties, without altering its constitution, or re-arranging its elements, without addition, or subtraction. The long and repeated digestion in carbonate of ammonia, has *produced* not *educed* crenic and apocrenic acids.—We are not informed of any other result, of any other product: no evolution of gas, indicating that any decomposition has occurred. From the acknowledged chemical tact of Dr. C. T. Jackson, we infer, that geine has afforded him only crenic and apocrenic acids. That these are the products of his process can then be easily understood.

The atomic weight of geine we have shown is 42. This number differs but little from the sum of the weight of two atoms of crenic acid, and one atom of apocrenic acid. Berzelius determined the atomic weight of crenic acid to be, 13.50

of apocrenic acid, 16.50

then 2 atoms crenic = 13.50 × 2 = 27.

1 atom apocrenic 16.50

43.50

Which differs only 0.89 from Boullay's number for geine, deduced from his analysis of ulmate of copper. But allowing the crenic acid, to be 12.75 we have then 2 atoms = 25.50

1 atom apocrenic = 16.50

42.00

And that 12.75 is probably the true number, will appear from re-arranging the atoms of geine, so as to constitute two atoms of crenic and one of apocrenic acid.—I have met with no analysis of the atomic constitution of these acids,* but taking their atomic weights, as above, and the result of Dr. C. T. Jackson, that geine is wholly separated into these acids, then the number of the atoms constituting their weight, is as follows:—

| | Crenic acid. | Apocrenic acid, |
|---|---|---|
| Carbon, | 11. = 8.25 | 10 = 7.50 |
| Hydrogen, | 4. = .50 | 8 = 1. |
| Oxygen, | 4. = 4. | 8 = 8. |
| | 12.75 × 2 + | 16.50 = 42 |

The number of atoms in 42 geine is 64. as above:

and we have 1 atom geine = $C^{32}$ $H^{16}$ $O^{16}$

*(Note.)—Hermann has given the following as the constitution of the crenic, apocrenic, and ulmic acids. (*American Journal of Science, &c. Vol.* 36, *p.* 369).

| | *Crenic.* | *Apocrenic.* | *Ulmic.* |
|---|---|---|---|
| Carbon, | 535.0 (= 7 atoms.) | 1070.1 ( = 14 atoms.) | 6190 |
| Hydrogen, | 99.8 (= 16 " ) | 87.2 ( = 14 " ) | 431 |
| Nitrogen, | 88.5 (= 1 " ) | 265.5 ( = 3 " ) | 1105 |
| Oxygen, | 600.0 (= 6 " ) | 300.0 ( = 3 " ) | 2274 |
| | 1323.3 (combining weight) | 1722.9 (combining weight) | 10000 |

It is hardly necessary to observe, that these results confirm the suggestion of Dr. Dana in the text, that crenic and apocrenic acids were not probably so constituted, as to be entirely converted into geine without an excess of any of the ingredients.

E. H.

| | | | | |
|---|---|---|---|---|
| Which resolved into | | | | |
| 2 atoms crenic acid, | = | $C.^{22}$ | $H.^{8}$ | $O.^{8}$ |
| 1 atom apocrenic acid | = | $C.^{10}$ | $H.^{8}$ | $O.^{8}$ |
| form one atom of geine | = | $C.^{32}$ | $H.^{16}$ | $O.^{16}$ |

It may be said, that it may be proved, that my statement of the atomic constitution of these acids is not confirmed by analysis. So much the better. That will prove, that geine cannot be a mixture of them. Though these elements theoretically admit of this arrangement, it is not at all probable, that nature forms crenic and apocrenic acids, out of which to form geine, by their complete chemical union; still less is it probable, that she merely mixes these acids. The constitution of geine is too firmly settled, to allow us to believe, that it is a haphazard mixture. The evidence of the existence of a simple proximate principle, geine, is rather strengthened, than weakened, by the above view of its probable theoretical changes. And as Dr. Jackson states that he has actually separated geine into two acids, he has furnished new and unquestioned proof of the existence of that principle. If the sum of the weights of his crenic and apocrenic acids equals the weight of the organic part of his soluble geine, he furnishes the highest evidence we can have, of the separate, independent existence of that element. I believe he has seen all that he states, and I must ask him to believe that the conclusions to which we have arrived, respecting the nature, constitution and properties of geine, are equally founded on experiment. While I thus freely admit the results he states, I express my conviction, that what he has seen, he has produced, that he has merely re-arranged the elements of a well known, definite compound, by the long continued action of ammonia. Such changes may not be readily comprehended by the majority, into whose hands your report may fall—all however now a days understand that there is such a thing as carbon, such elements as oxygen and hydrogen, which last by their union produce water. Now it is evident, by a glance at the above arrangement of the elements of geine, and crenic and apocrenic acids, that these are each and all, resolvable into carbon and water. We may as well deny the existence of crenic and apocrenic acids because resolvable into carbon and water, as to deny the existence of geine, because resolvable into crenic and apocrenic acids. A glance too at the above arrangement, will show us how crenic becomes apocrenic acid by simple exposure; for by absorbing oxygen, each atom parts with 6 atoms carbon, and then 2 atoms crenic form one of apocrenic acid; for,

| | Oxygen. | Hydrogen. | Carbon. |
|---|---|---|---|
| 2 atoms crenic acid, | 11 | 4 | 4 |
| | 11 | 4 | 4 |
| | 22 | 8 | 8 |
| Deducting 12 Carbon, | 12 | | |
| form 1 atom apocrenic, | 10 | 8 | 8 |

It is this change, which may account for the great evolution of carbonic acid, which attends the exposure of geine to air. The alkaline, earthy and metallic bases of the silicates of soils, as they are eliminated by the decomposing action of growing plants, all effect catalytic changes in geine. But without these, geine itself is decomposed by air and moisture, evolving volumes of carbonic acid. It becomes in every, and the widest sense, the food of plants, whether we consider it taken up as a simple solution of geine, or geates, or as a prolific source of carbonic acid. I do not however consider carbonic acid as vegetable food, or as playing a very important part in the nutrition of plants. Jablonski tried to verify the idea of Raspail, and to determine how much is due to the action of carbonic acid. The whole series of his most carefully conducted experiments, feeding plants only on carbonic acid and water, lead to this conclusion,

*that carbonic acid and water do not sustain plants, after the vegetable nutriment deposited in albumen or the cotyledons has been exhausted.* I did never suppose, till I learnt it from you, that any one could have believed that I denied that plants absorb nourishment from air. Speaking wholly of soils, and that by letter, I confined my remarks strictly to the nourishment derived from the earth. But extending the remark to air, geine is the great source of carbonic acid even then, and as far as carbonic acid is absorbed by the roots of plants, is perhaps its only source. I go farther. I believe that geine was, before organic matter, an original formation, dating its birth from the dawning of time, when oxygen and hydrogen and carbon were created. I believe it to have been an original formation, the source whence were nourished the gigantic plants of coal formations, and of itself, forming a large part of such deposits. Hence we find little or no alkalies in our analysis of coal—a little silica, iron, lime and alumina only having been formed as geates, in this early age.

I have not thought it worth while, to go into an examination of the practical value, to agriculture, of the doctrine of the mixed nature of geine. If it has any value, it depends entirely on showing that crenic and aprocrenic acids require different treatment from geine, and on determining the proportion in which these acids exist in soils. The first has not been done, the last never will be effected. It cannot be. We see these acids passing from one to the other state even during our manipulations; how then can we determine in what proportions they existed in the original soil? It may be said, that we can estimate them all, as crenic acid, as Berzelins has, in his analysis of the water of the Poria well. In this case, so far as agriculture is concerned, we may call them geine. With the highest regard, I am

Your Friend and Servant.

SAMUEL L. DANA.

PROF. HITCHCOCK.
*Amherst.*

P. S. I do not ordinarily use the oxygen scale. The statement above being chiefly derived from Dr. Thompson, I have employed his numbers for your convenient reference.

## VI. FOSSIL FUEL.

Next in importance to the means of improving our soils, I have regarded the discovery of fossil fuel; that is, fuel dug out of the earth, and resulting from vegetables which have been buried there in former times; and therefore, I have examined with no small care, every spot where such discovery seemed likely to be made. When I prepared my first Report, I confess my xepectations were not sanguine that Massachusetts contained within her bosom any extensive deposits of coal; though aware that not a little peat might be found. But since that time, the enterprise and industry of some of our citizens have put quite a different aspect upon the subject so far as coal is concerned; and I have made such extensive inquiries respecting peat, as leads me to suppose its quantity in the state has been much underrated. I will now proceed to give such details as will enable the Government to form an opinion on the subject.

Of fossil coal there exists three well marked species. The first is anthracite, or stone coal, sometimes called anasphaltic, because destitute of bitumen, and therefore burning without flame: though the anthracite of this country gives off a feeble flame, resulting from the combustion of hydrogen, which is evolved from its combination with the carbon; or more probably from water. The second variety is bituminous coal; so called because it contains bitumen. This burns with a white or yellow flame, and is the kind of coal

most commonly used; except in this country, where anthracite is most extensively employed. The third variety is lignite; which is a more recent kind, not yet entirely carbonized or bituminized. Hence it is sometimes called *brown coal.* As fuel it is of little value; but has been used in some parts of Europe.

We have all these varieties of coal in Massachusetts; and I shall now proceed to describe all their known localities.

## *Anthracite of Worcester.*

Only two large deposits of this species coal have yet been discovered in Massachusetts, one in Worcester, and the other in Mansfield. Several important localities, however, occur on the borders of the state within the limits of Rhode Island, which I shall notice more particularly farther on. But I shall begin with the Worcester deposit, because this is obviously older than those of Mansfield and Rhode Island.

By some of our earlier geological writers it was asserted that the Rhode Island coal deposit was connected with that in Worcester. But a reference to the geological map will show, if I have not been grossly mistaken, that no such connection exits: that in fact the different deposits are in very different formations. While those of Mansfield, and Rhode Island are in rock certainly not older than the graywacke, that in Worcester is in a bastard kind of mica slate; passing sometimes into quartz rock, and at others into argillaceous slate. No trace of organic remains has been found in this rock, while the other abounds in vegetable impressions and petrifactions. The character of the coal corresponds to these differences in the rocks. That from Mansfield and Rhode Island resembles very much the anthracite of Pennsylvania; except that occasionally it is more glazed with plumbago; while that from Worcester is often converted into plumbago. In fact, a good deal of it is ground up and employed for some of the same purposes as black lead. Its aspect is much more stoney than that of Mansfield, and its specific gravity is 2.12; while that of Mansfield and Rhode Island, is 1.75: and that of Pennsylvania, is 1.55. In short, I consider it established beyond all doubt, that the Worcester coal belongs to an older formation, and is in fact almost converted into graphite. The two formations have no connection whatever; and are separated by a wide district of gneiss.

The Worcester anthracite forms a bed in a carbonaceous mica slate, approaching closely to argillaceous slate, running nearly N. W. and S. E. and having a moderate dip to the northeast. It has not been explored but a few feet in depth. Before the work was abandoned by its enterprizing proprietor, Colonel Binney of Boston, an attempt was made, by going down the hill on

which the bed is situated, and taking off the soil, to reach the lateral outcrop of the coal; which could probably have been easily accomplished, and would greatly facilitate the operations. I have been informed by Dr. Amos Binney of Boston, the present proprietor, that he intends resuming the work.

As might be expected from a coal so mineralized, the Worcester anthracite ignites with much more difficulty than that from Penesylvania, or Rhode Island. But gentlemen who have tried it, for warming their houses during the winter, among whom may be mentioned Mr. Thomas for many years the keeper of a hotel in Worcester, have assured me that it may be used comfortably and successfully for fuel. And in some manufacturing establishments it is preferred to most kinds of coal. Its analysis, however, indicates more earthy impurity than exists in most good coals. An ordinary specimen yielded as follows in 100 parts.

| | | |
|---|---|---|
| Water, | 3 | |
| Carbon, | 77 | |
| Earths and oxides, | 20 | |
| | 100 | Specific Gravity 2.12. |

A second specimen, almost converted into plumbago, yielded as follows.

| | |
|---|---|
| Water, | 2.4 |
| Earthy Residuum, | 26.6 |
| Carbon, | 71.0 |
| | 100.0 |

According to the experiments of Mr. Bull of Philadelphia, a pound of the best Pennsylvania anthracite maintained ten degrees of heat in a room, 13 hours and 40 minutes, a pound of the Rhode Island anthracite maintained the same heat in the same room, 9 hours 30 minutes; and a pound of the Worcester anthracite, 7 hours 50 minutes. Theory and experience, therefore, concur in bringing us to the conclusion, that the Worcester coal is of an inferior quality. Yet in a country so wanting in coal as New England, a deposit of inferior coal is not to be regarded as useless. The time will probably come when it will be regarded as very valuable.

By looking at the Geological Map of the State, it will be seen that the rock formation which embraces the Worcester coal, extends to the mouth of the Merrimack river; and of course, coal may be found in other parts of the formation besides Worcester. In Bradford, where the general aspect of the country, the character of the soil and of the rocks, correspond almost exactly to the region around Worcester, an exploration is going on for coal by means of boring, which has been continued to the depth of nearly one hundred feet. I saw, however, no peculiar encouragement

at this place, more than at almost any other in the town. Should coal be found there, it will undoubtedly be of the same character as that in Worcester.

## *Anthracite of Bristol and Plymouth Counties and of Rhode Island.*

In my Report of 1835, I stated that we might reasonably look for anthracite coal in any part of the graywacke formation exhibited on the Geological Map. This exists in several patches in the eastern part of the state: viz. a small deposit on Parker river in Newbury; a much larger one around Boston; and the principal one, in Bristol and Plymouth Counties; extending also into Rhode Island. The latter covers an area of nearly 400 square miles: and upon this I marked on the map one locality of coal in West Bridgwater, one in Middleborough, and one in Wrentham; as also in Cumberland and Portsmouth in Rhode Island. In the autumn of 1835, a bed was discovered in Mansfield, which has since been considerally explored, and with others in that place, has proved more important than any other, and excited sanguine expectations that the region may prove an extensive and valuable coal field. Coal had, indeed, been discovered in that place 25 years before: but it was not till 1835, that any systematic efforts were made to explore the beds. Three mining companies have since been formed: viz. "The Massachusetts Mining Company," "The Mansfield Mining Company," and the Mansfield Coal Company;" each of which has opened a pit at different places; and in spite of the stagnation of business and enterprise, and the general incredulity in respect to the existence of valuable coal, they have been so far successful as to satisfy any reasonable men acquainted with coal formations, that a great deal of that mineral may exist beneath the deep diluvial coat of that region. I shall describe the principal excavations made by these companies, with the results to the close of 1838: when the operations were suspended, with the hope of obtaining aid from the Government of the State, to resume them on a larger scale. I have been informed that in the commencement of their efforts, they derived much assistance from the suggestions and advice of Dr. C. T. Jackson, the Geological Surveyor of Maine and Rhode Island.

The Massachusetts Mining Company commenced their explorations in 1835, on the farm of Mr. Alfred Harden, where a shaft sunk only 25 feet, struck a bed of coal 5 feet wide, and another only 1 foot thick, separated from the first by 10 inches of rock. The shaft has since been carried to the depth of 64 feet; and from the bottom of it, in opposite directions and following the bed of coal, drifts have been extended 150 feet, and rail-ways laid for bringing the coal to the bottom of the pit, from whence it was, until recently, raised to the surface by a windlass and hand power; but steam power is now used, which greatly increases the daily amount of coal raised. About 1,500 tons had already been raised from this mine, when I visited it in October,

1838 ; and a drift had been carried from the bottom of the shaft, in a south-east direction, several feet across the rock strata, in search of new beds. Only one about a foot thick had been reached.

The explorations at this spot have been carried forward under the direction of Gen. Samuel Chandler, of Lexington, who seemed to me to have managed the whole concern with remarkably good judgment, and to have brought the principles of science to bear upon practice with singular success. In his printed Report to the Company, he says, that "although the region has been but very imperfectly explored, even where the strongest external evidence appears, yet four separate veins are known to occur on land leased to the Massachusetts Mining Company, situated at no great distance apart, and parallel in their line of bearing: two of which have been opened sufficiently to ascertain their thickness to be over five feet," &c.

The clerk of the company, William B. Dorr, Esq., makes the following statement in respect to these explorations, which must be regarded as very encouraging. "The Massachusetts Mining Company," says he, "at an expense of less than $15,000, with all the discouragements of a novel undertaking, the almost entire want of practical knowledge of the subject, and the cost of experiments which experience would have rendered unnecessary, have been able to raise from 1200 to 1500 tons of coal, worth from $5000 to $6000, at the lowest estimate both of the quantity mined and of its true value." "The directors have unhesitating confidence in the eventual success of the mining operations at Mansfield ; and nothing but the universal prostration of enterprise and business, has prevented their pursuing these operations on a scale commensurate with their confidence and the public importance of the subject."

There are two methods of ascertaining the value of this coal for fuel: both of which it is desirable should be applied. One is chemical analysis: by which we learn how much carbon, or combustible matter, it contains, and how much earthy residuum that is useless : and the other is experience in using it. In 1835 Dr. C. T. Jackson analysed two specimens taken from the depth of about 25 feet, and the results were as follows :

| *1st. Specimen.* | | *2d. Specimen.* | |
|---|---|---|---|
| Carbon, | 98 | Carbon, | 96 |
| Peroxide of iron and alumina, | 2 | Peroxide of iron and alumina, | 4 |
| | 100 | | 100 |

I have made but two trials with specimens obtained at the mine in 1838, and the result is as follows:

| *1st. Specimen.* | | *2d. Specimen.* | |
|---|---|---|---|
| Carbon, | 94 | Water, | 5.6 |
| Residuum, | 6 | Carbon, | 88.8 |
| | | Residuum, | 5.6 |
| | 100 | | |
| Specific Gravity, 1.70. | | | 100. |

The amount of carbon in these specimens is a little greater than Prof. Vanuxem obtained from two specimens of anthracite from Rhode Island. In one he found an earthy residue of 5.07 per cent. and in the other of 15.60 per cent. He also found about the same per cent. of water as I obtained in the second trial; this item having been neglected by me in the first trial, as well as by Dr. Jackson, as our chief object was to ascertain the amount of earthy residuum. The amount of carbon in the Mansfield coal is nearly equal to that in "the purest anthracite of Lehigh," in which Prof. Vanuxem found 3.3 per cent. of earthy residue, and the mean of the

four analyses given above is only 4.4 per cent. of residuum. The composition, then, indicates the very best kind of anthracite. Its specific gravity, however, is 1.70; while a specimen of Peach Mountain coal in Pennsylvania, was only 1.49; and hence, perhaps, we might expect some more difficulty in producing perfect combustion in the former than in the latter.

As to the testimony which experience gives to the value of this coal, so far as that testimony is within my reach, it corresponds to what chemical analysis would indicate. It ought to be recollected, however, that beds of coal near the surface of the earth, are always more less affected by the action of water, which insinuates itself into their crevices. I have understood, that from this cause the coals of Pennsylvania have improved since the beds were first opened. It ought also to be recollected, that coal from a new locality may be expected to require a little different mode of management to make it burn well; and also that when men do not find such new article to conduct precisely like that which they have been accustomed to use, they are apt to infer at once that it must be of an inferior quality; and they are not willing to be at the trouble of making experiments to get over the difficulty.

"The quality of this coal," says Gen. Chandler, "has given very good satisfaction generally to the purchasers, notwithstanding it was taken by many under unfavorable circumstances."— "Many competent judges who have had opportunties of testing its qualities thoroughly, represent it equal, in their opinion, to the Pennsylvania Anthracite in all its essential properties."—"The fine coal has been taken in considerable quantities and used as fuel for steam power, and proves to be a very superior article for that purpose, &c."

Foster Bryant, Esq., of Mansfield, who appears to be very familarly acquainted with all the mining operations in that region, states, that as the beds have been explored to greater depth the quality of the coal has improved, which he imputes to the action of the water upon the upper portion of the beds. This often prevents the thorough combustion of the coal, although it ignites without difficulty and burns well for four or five hours. He adds, that "the coal of Mansfield, even in its present impure state, is capable of being converted to all economical purposes, and contaminated as it now is by adventitious substances, it is a better, far better article, than the coals from the Little Schuylkill were in 1831, and altogether better than the first year's produce from the Lackawana mines."

"The quality of the coal," says Mr. Dorr, "has afforded entire satisfaction to those who have taken the pains to give it a thorough trial, and to investigate its distinctive properties. Several of the directors use it exclusively for fuel, in open grates, cylinder stoves, and cooking ranges. It is found to ignite and burn best with a very moderate draught: and broken to about the size of a butternut. Uniformity in size is of course desirable. Under favorable circumstances, little difference is found in comparison with the best Pennsylvania anthracite, whether in relation to facility of ignition or intensity and durability of heat."

"The community generally, from feeling less interest in its success than the proprietors, will naturally take less pains in its use; and like every new discovery, its general introduction will doubtless be gradual."

In my Report of 1838, I adduced the testimony of Capt. Bunker and 35 passangers, of the steam boat President, on board of which the Mansfield coal was used during a trip from Providence to New York. They regarded this coal "fully equal to the Pennsylvania coal in all essential properties." In a Report on the Coal Mines of the state, made to the Legislature of Massachusetts in 1839, we have a similar certificate from 16 of the inhabitants of Mansfield who had used the coal in their stoves and families. They state that "the coal taken from 26 to 50 feet in depth was poor, and much of it scarcely capable of combustion," but "that taken from the depth of 60 feet and upwards, is equal to the Pennsylvania coal in all respects excepting a larger portion of waste," (p. 34.) A short account which I shall give in the sequel, of the coal mines of Rhode Island, will tend to confirm this testimony still farther.

## *Explorations of the Mansfield Coal Company, and the Mansfield Mining Company.*

The Mansfield Coal Company have simply sunk a shaft of 64 feet near the center of Mansfield, but have met with only a little coal: another shaft was sunk, half a mile north-west of the Harden farm, by the Mansfield Mining Company, to the depth of 84 feet, in which a bed only a few inches thick was crossed. A drift was then commenced at the bottom of this shaft, horizontally, towards the southeast so as to cross the strata. This had not been pushed far, when a bed of coal was struck, which, at the place, was about 10 feet thick; though on exploring it laterally for a few feet, it was found to be somewhat irregular; as indeed most of the beds are in the region, and as they are in fact in all coal fields. In crossing this vein, 25 tons of coal were thrown out, some of which is of a very superior quality; as may be seen in the collection (No. 207.) For specimens I am indebted to Mr. Joseph D. Clapp, the agent, who informs me that this vein has received the name of the "Wading Vein." When I visited it in October it had recently been discovered, and I have not since learned whether it has been pursued farther. I subjected 100 grains of it to analysis with the following result.

| | |
|---|---|
| Carbon, | 96 |
| Alumina, Iron, &c., | 4 |
| | 100 |
| Specific Gravity, | 1.79 |

We have seen, from the testimony of Gen. Chandler, that four distinct beds of coal are already known upon land leased to the Massachusetts Mining Company. Mr. Foster Bryant states, that "seven distinct veins of coal have been struck in Mansfield, and the strongest indications are found of five more, one of which, from its great breadth is probably a continuation of the great vein at Cumberland." This is a great number to be discovered so early. For it ought to be stated that the whole of that region is covered by a coating of diluvial earth nearly 20 feet thick; so that it is only when in digging a well, or other excavation, that much chance exists for discovering the coal: for I could not learn that any streams in the vicinity have cut through this diluvium. The fact that with such peculiar difficulties in the way, so large a number of beds have been discovered in the space of a little more than two years, is to my mind a very strong proof that the region of Mansfield is likely to prove a very rich and valuable coal field. By looking at the Geological Map of the State it will be seen that the greywacke formation embraces a large part of Bristol and part of Plymouth counties, as well as a part of Rhode Island. All this space which Mr. Bryant estimates at more than 400 square miles, is to be regarded as a coal field; and indeed, on the northern side, which is nearly 30 miles long, coal has been found in various places through the whole distance. A very large part of this extensive region is covered by a thick coat of diluvium, as in Mansfield; and where rocks appear in place above the surface, they are those varieties of the greywacke which are least likely to contain coal, being coarse and hard. The coal usually occurs in fine dark colored slate, alternating with gray sandstone: and these are very liable to be disintegrated and worn away. Hence, the best prospect of finding coal is where the rock is most worn away, and the soil deepest. Such is the rock every where found in Mansfield, and since an almost perfectly level plain exists there, over many square miles, I infer that the rock is very similar over its whole extent; and hence that probably we may hope for more success in explorations there, than in almost any other part of the coal region above described.

It is a fortunate circumstance that the great Rail-Road from Boston to Providence passes across the center of the plain of Mansfield, and within 20 rods of the Harden farm, where the most extensive exploration has been made. From this spot it is 15 miles to Providence, 11 to Taunton, and 26 to Boston. A more favorable situation could hardly have been chosen for the location of this coal, had the proprietors themselves selected the site.

Coal rarely occurs in *veins*, properly so called: that is, occupying fissures *which run across the layers of the rock*. But it is uniformly found lying *between* the layers of the rock; that is, in what are called seams, or *beds*. If the layers of the rocks are horizontal, the beds will be horizontal. But generally, and especially in the graywacke formation, the strata dip more or less beneath the horizon, and of course the coal beds dip at the same angle. Being thus inclined, they will also run in the same direction as the upturned edges of the rock in which they are contained. Hence every coal bed will have a certain dip and direction. The extent to which the bed on the Harden farm in Mansfield has been opened, viz, 150 feet each way from the shaft, affords a good opportunity to determine these points in respect to that mine. I applied the clinometer and pocket compass at the bottom of this mine, and found the dip to be 53° north-westerly, and the direction nearly N. E. and S. W., though exhibiting minor deviations. And such are the dip and direction, within a few degrees, of all the rocks and coal beds that have been explored in the graywacke of Bristol County, and in Rhode Island; except that on the Island it is said the dip is nearly 90° south-easterly.

Now it is evident, that if a trench could be cut through the loose soil across the edges of the strata, it would bring into view all the beds of coal that exist in them. But several gentlemen who are practically acquainted with such operations, assure me, that such a trench would be far more expensive than it would be to sink a shaft several hundred feet into the rock; and then to push horizontal drifts through the rocks at right angles to the strata. And besides, were this done, and a rail-way laid at the bottom of the drift, as soon as a bed of coal was discovered, the mining and raising of it might immediately commence, without preventing the further prosecution of the drift.

This, then, appears to me, the thing that is wanted in the region under consideration. Suppose such a shaft, for instance, to be sunk 300 or 400 feet in the vicinity of the mine on the Harden farm, and a drift extended in opposite directions across the strata. We might be almost certain that these drifts would cross several valuable beds, since they are already known to exist in the vicinity. And thus the proprietors might have a fair prospect of remuneration, even if no new beds should be discovered: since this would probably, in the end, be the most economical way of opening the beds now known. But it is hardly to be conceived that no new and valuable beds would be discovered by extending the drift farther. Yet if they should not be found after carrying it forward a reasonable distance, it might be abandoned with little loss. How far it might be thought advisable to prosecute such a drift, it is difficult to say, until the work be begun: but perhaps it would be desirable to extend it several miles; which might be done, I understand, for less than $25,000 per mile, exclusive of the cost of the shaft. I should not be surprised if in tunneling towards the north-west, from the center of Mansfield, at the depth of 300 or 400 feet, the level should, ere many miles, be arrested by unstratified rocks, which rise to the surface within a few miles in that direction, and the graywacke may be thinner near the edges of the formation than in its more central parts. In the opposite direction, I should not expect any such obstruction, till the drift had been carried to the eastern part of Middleborough.

I have been told that the three companies above named, as engaged in mining for coal in Mansfield, have thought of uniting their resources for examining the vicinity of that place, by a plan essentially the same as that mentioned above. This resolution is certainly deserving of high commendation. For should these companies succeed in laying open a sufficient number of beds of coal to supply the wants of the eastern half of Massachusetts, (and I am not without strong

hopes that they may succeed,) so as to render our citizens independent of foreign importation, and reduce the price of fuel at least one half, hardly anything can be thought of that would give such a spur to industry and enterprise, and tend more to permanent prosperity. And allow me to inquire, whether the object is not of sufficient importance, and the prospect of success encouraging enough, to induce the Government of the State, by loan or otherwise, to encourage this undertaking. In general, it is probably best to leave such enterprises to private efforts; but in this case the investments must be so heavy that private companies may not feel justified in appropriating sufficient money to have the work done thoroughly: and if the Government, probably without any pecuniary loss, can lend its aid, it will give a powerful stimulus to private exertions. I make this suggestion, however, without any request on the part of these companies, and even with scarcely a personal acquaintance with any of their number.

It will probably surprise most of the citizens of Massachusetts to be informed, (as we are by the able report on our Coal Mines above referred to,) that about *two and a half millions of dollars* are annually sent out of the state for fuel! Not less surprising is the fact that Pennsylvania realizes from her coal mines an annual income of four and a half millions; and Great Britian, of 192 millions of dollars.

## *Diluvial Drift of Coal.*

General Chandler mentioned to me a mode of exploring for coal, which he had successfully adopted, and which may be of use to others, depending on a knowledge of the direction which was taken by the diluvial waters that deposited the deep accumulation of sand and gravel lying over the coal region. It is an ingenious practical application, and at the same time a beautiful illustration and confirmation of the general doctrine advanced in my former Report, that a powerful diluvial current has swept over this state from the north. Whenever in digging into the soil he found fragments of coal, guided by this principle, he dug in a northerly direction; and never failed to find the number and size of the fragments to increase until he arrived at the bed from which they were broken. Following the fragments in the opposite direction, they continued to decrease in size and number until at the distance of several rods from the bed they disappeared. Hence, if in digging through the soil no fragments of coal should occur, it might pretty safely be inferred that no bed of much size exists for several rods in a northerly direction; and if they are found, the explorer need be at no loss in what direction he will find the bed.

## *Coal Bed in Foxborough.*

I ought perhaps to have described the coal bed in Foxborough earlier. For it is only about two miles from the excavations in Mansfield, and belongs to the same coal field. Good coal was obtained there, formerly, in two places a few rods apart: but the shafts are now filled up. A specimen of this coal gave the following results upon analysis:

| | |
|---|---|
| Water, | 5 |
| Carbon, | 77 |
| Earths, oxides, &c., | 18 |
| | 100 |

Specific gravity, 1.86.

The quantity of earthy matter here is much larger than in the specimens from Mansfield; yet it is not much larger than some of the coals contain that are extensively used; and very probably the specimen which I analyzed was comparatively poor. It is not probable, however, that this bed will be re-opened at present.

## *Anthracite in Wrentham.*

Several excavations have been made in the southerly part of Wrentham for coal: but only in one place has any been found: although some interesting vegetable relics have been brought to light at nearly all the pits. At the place where some anthracite has been discovered, an exploration 180 feet deep has been made; all except 10 feet, in a dark carbonaceous slate, running nearly east and west, and dipping north about 45°. The specimens of coal were a good deal mixed with earthy impurities and iron pyrites. Nevertheless I analyzed one of them with the following results.

| | |
|---|---|
| Water, | 6.6 |
| Carbon, | 50.4 |
| Earths, oxides &c. | 43.0 |

Unless a purer variety than this can be found, it will hardly be worth exploration; and in fact the exploration has been abandoned; as beds, even of a variety so poor, have been yet found only a few inches thick.

## *Anthracite of Rhode Island.*

I notice in this place the coal of Rhode Island, first, because it is found in the same coal formation which occupies the southern part of Massachusetts: secondly, because the beds lie so near to Massachusetts as to be as important to her inhabitants as to those of Rhode Island: and thirdly, because some of these beds have long been wrought and experiments were made to determine the value of the coal for fuel: and therefore will help us in forming an opinion respecting the coal of Massachusetts.

The coal bed in Cumberland, which is only a mile or two from the Massachusetts line, was discovered and opened somewhat earlier than those in Mansfield. The dip and direction of the beds are the same in both places. The bed in Cumberland was 9 feet thick at its outcrop, beneath 20 feet of diluvium: but at the depth of 40 feet, it had increased to 14 feet. It was explored 70 feet deep, or 300 feet laterally, when the work was suspended by the destruction of the machinery by fire. The testimony of Mr. John Alexander, the agent of the N. England Coal Mining Company, by whom the mine has been opened, and of several other gentleman who seem to have given the coal a fair trial, is very decided that this coal is of a good quality, not inferior to that in Mansfield, and scarcely inferior to that from Pennsylvania. It is also the uniform testimony, that it increases in value as the depth increases from which it was obtained. (*Report on the Coal Mines of Massachusetts p.* 29.) It is greatly to be desired, that the application of this Company to the Government of Rhode Island for aid in reopening this mine, may be successful.

In the south part of Newport, on the island of Rhode Island, beds of anthracite occur a few inches in thickness. During the revolutionary war, the British army, after consuming nearly all the wood upon the island, attempted to find coal at this place; and the marks of their explorations yet remain. But near the beginning of the present century, more extensive excavations were made at Portsmouth, in the north part of the island, and with no little success.

Dr. Meade says, that the vein then wrought was 14 feet wide; and 'with only fifteen work men, they can raise at present from 10 to 20 chaldrons of coal per day, besides keeping the mine free from water; from which they suffer little inconvenience.'* He speaks of the bed of coal as 'not horizontal or vertical, but forming an angle of about 75.°

* Bruce's Mineralogical Journal, January, 1820, p. 84.

A great variety of causes led to the abandonment of these explorations; but a few years since they were again resumed; and through the kindness of Dr. Thomas H. Webb, of Providence, I have before me a letter addressed to that gentleman, from J. Clowes, the intelligent agent employed to superintend this second exploration; from which I derive the following facts respecting the anthracite of Portsmouth. The letter is dated February 18th, 1828; which appears to have been about the time when the work was the second time abandoned.

The quantity of anthracite raised at these mines in 1827, by 20 men and 5 boys, was 2200 tons, and an equal quantity of *slack*: that is, very small coal and dust. The former sold at the mine for $4.50 per ton, of 2240 pounds; and the slack for $1 per ton. The slack was used for burning lime and bricks. The best coal was mostly employed for fires in families, except in New York, where it was used for making glass; for generating steam under the common circular or round boiler; for blacksmiths; and in general for any purpose where anthracites are employed.

The agent regards these mines as capable of furnishing an inexhaustible supply. He represents the coal as occurring in veins; but his descriptions apply rather to beds; and I am almost certain that it occurs in beds. Six of these have been expcsed; and more than 30 are said to exist in that part of Rhode Island. Their direction is southwest and northeast, and they dip southeast from 40° to 90.°

The following are the strata that were penetrated in sinking a *water shaft*, or *engine pit*, 87 feet; and in fifteen other places they were found to be very similar.

| | |
|---|---|
| Sand and Gravel, | 9 feet. |
| Dark Colored Slate, | 12 |
| Hard Compact Graywacke, | 23 |
| Soft Black Slate, | 4 |
| Hard Brown Slate, | 5 |
| Soft Fine Gray Slate, | 1 |
| Very Hard Brown Slate, | 17 |
| Gray Freestone, | 12 |
| Coal, | 4 |

Vegetable remains were found only in one of these excavations, about nineteen feet below the surface.

The failure of the mining operations in Portsmouth, between the years 1809 and 1816, resulted, according to Mr. Clowes, from two general causes: 1. A want of practical skill in those who conducted the operations. This prevented as much system in the works as was necessary, and also the introduction of proper and economical machinery. And he says, that 'amongst the many losses, which contributed to work their ruin, that was not the least, of allowing or permitting the workmen to have from half a pint to a pint of spirituous liquors during the working hours. We neither allow nor permit any thing of the sort, nor is it allowed or permitted in any mining establishment in Europe. Instead of benefitting a man it actually incapacitates him: and exclusive of the immoral effects on the passions of the workmen, I consider it a loss to the owners of at least one sixth of the whole manual labor.'

The second cause of failure, he says, lay in sending the coal from the mines in an improper state; that is, unsorted, and in too large lumps. He says that the Rhode Island coal does not break easily when ignited, like the Lehigh coal, and that this fact and the amount of impurities which it contained, injured its reputation in the market. He thinks that if mixed in equal quantity with the Pennsylvania or bituminous coal, it answers best for fuel: and he says he has abundant evidence, that one ton of the Rhode Island coal, mixed with a ton of that from Pennsylvania, is equal to two tons of the anthracite from the latter state.

Numerous experiments were made a few years ago, and are detailed in the eleventh volume of the American Journal of Science, by Mr. Bull of Philadelphia, and Professor Silliman of Yale College, to determine the comparative value of the Rhode Island and Pennsylvania anthracite: and the fair conclusion from all their experiments is, that the former is not much inferior to the latter. Now as the Mansfield anthracite belongs to the same continuous formation, and can hardly be distinguished from that of Portsmouth, by its external characters, the same conclusions will apply to both. But even though we should admit that the New England anthracite is a good deal inferior to that from Pennsylvania, it may still be very valuable.

The fact is, anthracite has to struggle with prejudices wherever it is first introduced, arising chiefly from the comparative difficulty with which it is ignited; and it happens in regard to this substance, as with most things new and untried, that the community generally feel, as if their business was to find as many objections to it as possible; and the man who would bring any new substance into general use, needs no small share of patience, and perseverance. Dr. Meade states, that an experiment made several years ago at Smithfield, upon the burning of limestone, with the Rhode Island coal, and another upon the burning of brick, in the vicinity of Boston, were thought to be complete failures, because the heat was so intense, that the surface of the lime and of the bricks was vitrified; whereas the fact ought to have taught the experimenters, that a more careful regulation of the heat would ensure success. Indeed, I predict, that ere long, in nearly every case where a strong and steady heat is required, anthracite will be found superior to all other kinds of fuel; and that the anthracites of Rhode Island, Mansfield, and even that of Worcester, will be considered by posterity, if not by the present generation, as a treasure of great value. The Pennsylvania coal may indeed, for many years, command the market; but I apprehend, that the time will come, when the expenses of its transportation to the Eastern States, and the increasing demand for it, will lead to the re-opening of the pits, that are now abandoned in New England.

In the sandstone in the vicinity of Connecticut river, anthracite has been found in very small quantities, at Turner's Falls in Gill, at the Southampton lead mine, whose adit penetrates this rock, and at Enfield in Connecticut. But this is probably bituminous coal, rendered anasphaltic by local causes.

The geological character of the rocks containing the workable anthracite of Bristol County and of Rhode Island, is a point of no small importance. In my former reports I have regarded this rock as graywacke and graywacke slate; and have considered them older than those containing anthracite in Pennsylvania; while the rock embracing the Worcester anthracite is older than either. The characters of these rocks, as well as of the coal, form the basis of this opinion: and although it seems probable from the researches of Prof. H. D. Rogers, that the Pennsylvania anthracite is in secondary rocks, yet I am still disposed to think that the coal region of Massachusetts and Rhode Island, must be referred to the transition series; that is to the graywacke. I did suspect that it might be of the same age as the anthracitous rocks of Pennsylvania: but upon re-examination, the arguments appear to me rather to preponderate against that opinion. I shall consider the subject in detail in the scientific part of my Report: but wish here to say, that even if the New England anthracitous formation be graywacke, it can militate but slightly against the probable value and extent of the coal which it contains.

Formerly I confess I had not great confidence that its value or extent was great. But more thorough examination and the development of new facts, have produced a sincere and strong conviction that both Massachusetts and Rhode Island possess in this formation a treasure, as yet mostly hidden, but which will be more appreciated as it is more developed.

*Bituminous Coal.*

The sandstone formation in the valley of Connecticut River is the only region in Massachusetts where bituminous coal has been, or probably ever will be found. As yet it has been discovered there only in thin beds of little importance; and it becomes an interesting question whether the prospect of finding larger beds is great enough to justify an extensive exploration. The first point to be determined is, to what part of the series of rocks is this sandstone formation to be referred? From the fact of its containing coal some have referred it at once to the coal formation. But from arguments which I shall present in the scientific part of my Report, I am forced to the conclusion that it belongs rather to the new red sandstone series; or that it is the equivalent of that formation in Europe.

Yet if this be admitted, shall we infer that there is no hope that it may contain coal in such quantity, and of such quality as to be useful for fuel? A few years ago, geologists would have peremptorily decided this question in the affirmative: but in the present state of their science, it seems to me we may at least reasonably hesitate, and perhaps draw a contrary inference. It is now generally admitted that all coal has a vegetable origin; and that simply by the long continued action of water, under certain circumstances, vegetable matters pass into the state of peat, next into lignite, then into bituminous coal, and finally into anthracite: though this last substance more commonly, perhaps, results from the action of heat on bituminous coal: and if the heat be powerful enough, even plumbago may be produced: 'as wood has been, thus changed,' says Dr. Macculloch,* 'in my experiments, and as coal is daily in the iron furnaces.' Such a change he found, in one case at least, produced upon common coal, in the vicinity of a trap dyke: hence he reasonably infers, 'that even the plumbago of the primary strata, no less than the anthracite, might as well have originated in vegetables, as that each of these should owe an independent origin to elementary mineral carbon.'

According to this theory, why may we not hope to find large quantities of workable coal in any formation where we find it in small quantities? For, the same causes that could produce it in thin beds, might reasonably be supposed adequate to the production of large masses. Anthracite is found in almost every rock from lias to gneiss; and bituminous coal occurs in the oo-

* System of Geology, &c. Vol. 1. p. 298.

litic and new red sandstone series, as well as in the proper coal measures.* True, so far as we yet know, the coal measures contain the principal deposits of the latter species in Europe; and perhaps in this country: But who knows whether the circumstances under which our new red sandstone was deposited, might not have been such as to produce extensive masses of coal? This would not constitute so great a difference between our new red sandstone and most of that in Europe, as the almost entire absence in the former of gypsum and rock salt; minerals which, on the eastern continent, are regarded as eminently characteristic of this formation. In Yorkshire, England, coal has been found in the new red sandstone: and on the European continent, as in Poland,† occasionally in thin seams: and it has been recently ascertained, that the Brora coal field in Scotland, which is probably the equivalent of that of Tecklenberg—Lingen, in Prussia, is contained in the lias;‡ a formation which lies above the new red sandstone; and, therefore, every presumption is in favor of finding coal in the new red sandstone; since this lies between the lias and the real coal measures. This conclusion is still farther strengthened by the fact, that Humboldt, Daubuisson, and other able geologists, consider the red sandstone group, and the coal measures, as belonging to the same formation.§ All these facts prove, it seems to me, that it was a hasty generalization which limited workable coal to the coal measures; and that, therefore, we should not be prevented from searching for coal in the new red sandstone of the Connecticut valley. And besides, it may be that the true coal formation lies beneath the red sandstone.

The coal in this rock occurs in the form of thin beds and irregular nodules, which are rarely but a few inches in diameter. In almost every instance, it appears to be the result of the carbonization of a single plant, whose form can be distinctly traced; though it is always broken into fragments, whose length rarely exceeds two feet. At Whitmore's ferry in Sunderland; in the north part of South Hadley, and on the north bank of Westfield river in West Springfield, the coal is highly bituminous: though least so at the last named locality. But at Turner's falls, in Gill; at the Southampton lead mine, and at Enfield falls, (Connecticut,) it is anthracite. At the junction of this same formation with the greenstone at Berlin, in Connecticut, Dr. Percival has described a vein of bituminous coal penetrating the greenstone. He says, however, that 'it more usually has the appearance of cinders so mixed up with siliceous matter as to be hardly combustible.'

It becomes an interesting inquiry, whether local circumstances will enable us to explain why

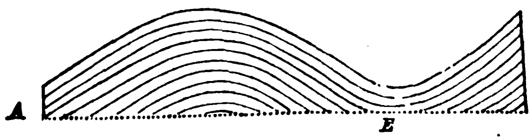
* See Brongniart's Tableau de la Succession et de la Disposition des Terrains et Roches, &c. Paris, 1829. Also Conybeare and Phillip's Geology of England and Wales, Vol. 1 p. 329. Al. Brongniart also describes, as occurring in the Plastic Clay Formation of Mount Meissner in Hesse, 'a true anthracite—that is to say, a dense carbon without bitumen, sometimes with a dull, sometimes with a shining fracture. We here find a thicker bed of compact, solid, bituminous carbon, having a nearly straight fracture, burning with facility, and presenting many of the characters of true Coal.' Phil. Mag. Vol. II. N. Series, p. 108.

† Conybeare's Report on Geology, (1832) p. 390.

‡ Philosophical Magazine, Vol. II. N. Series, p. 101.

§ De la Beche's Geological Manual, 2d. Edition, (London, 1832.) p. 405.

the coal at some of these localities is bituminous, and at others anthracite. 'We know,' says Prof. Al. Brongniart,* 'that the coal which is in contact with the veins or dykes of basanite, or trap, that traverse it, and that which approaches masses of porphyry, is less bituminous than other portions of the bed, and that it even loses all its bitumen, and in passing to the state of anthracite, exhibits, as it were, a kind of vitreous texture, &c.' Few geologists will now doubt but the proximity of granite produces a similar effect. Now at Turner's falls we know that a large mass of trap is not far from the coal; and at Southampton, that granite is still nearer; and hence we should expect the coal at these places to have lost its bitumen. I am not aware, however, of the proximity of either of these rocks to the coal at Enfield falls; though ignorant of its particular location. At Sunderland and South Hadley the trap is so far distant, that we are not surprised to find bitumen. The existence of bituminous coal, however, in the trap at Berlin, Ct. is quite remarkable; and the fact that a portion of it is converted into pseudo cinders, proves that heat does not necessarily drive out the bitumen. The contorted condition of the strata at the locality of coal in West Springfield, renders it quite probable that trap rock exists a short distance beneath the surface. The pretty uniform dip of the strata, where they are laid bare in that town several miles in width, by Westfield river, is from 15° to 20° east. But at the spot




just referred to, we find the anomaly which is here sketched. It is a satisfactory explanation of this case to suppose that greenstone, or some other igneous rock, has pressed upwards with such force between A and E, as to give to the strata a saddle shaped appearance for a few rods. (Four rods from A. to E.)

### *Bituminous Coal, West Springfield.*

Within a few years past, the banks and the bed of the river at the place above sketched, which is called Midneag Falls, have been somewhat extensively excavated for building factories. The consequence was, the bringing of coal of the most beautiful variety, that I have ever seen; a specimen of which is in the State Collection. It appears to exist here in the form of small and irregular veins, the coal also being filled with numerous thin veins and crystalizations of calcareous spar. This is a most remarkable mode of occurrence, and very interesting in a scientific point of view: and perhaps, also, of consequence in a practical point of view: otherwise I should not here describe it. Coal is, indeed, described in geological books as sometimes occupying fissures in rocks, along with fragments of those rocks: but in this case the coal is broken by mechanical violence. Yet at West Springfield, it has evidently been filled into the fissures, just as the associated calcareous spar was, by a chemical agency. The latter may have been deposited from water: but I can conceive of no way in which the coal could have been formed, but by sublimation and consequent solidification, as the temperature was reduced.

* Tableau des Terrains &c. p. 283.

In short, my supposition is, that coal may exist beneath this spot, and that by the agency of trap rocks, a part of it was melted, the superincumbent sandstone forced up, and into its fissures the sublimated coal ascending, but not being able to escape, was reconsolidated into coal. I am aware of but one analogous fact having been noticed elsewhere,* and this makes me less confident in this hypothesis. Yet every fact respecting the situation of this coal corresponds to it, as does also its chemical composition. For if it were the result of sublimation, we might expect it to be free from those earthy and metallic matters, that I believe have always been found in coal upon analysis. And such it will be seen, is the fact with the West Springfield coal: or rather it is free from impurity as most crystals are. It is, indeed, difficult to separate mechanically from this coal all the thin layers of calcareous spar with which it abounds, and hence there will often be a small residuum after burning in a platinum bowl: but diluted cold nitric acid dissolved this almost entirely, with effervescence in three trials which I made; and hence I conclude it to be carbonate of lime, which ought not to be reckoned as an impurity, because existing only in the fissures of the coal, and subsequently introduced.

A pure specimen of this coal yielded, upon analysis, as follows:

| | |
|---|---|
| Volatile matter, (water and bitumen,) | 22.00 |
| Carbon, | 77.97 |
| Earthy residuum, | 0.03 |
| | 100. |

The method which I adopted to ascertain the amount of volatile matter was simply to heat the triturated coal in a broad platinum bowl, nearly to redness, until all the bituminous odor had disappeared. This, I am aware, is not a very satisfactory mode of determining the amount of bitumen; but it is sufficient for my present purpose to show, that a large proportion of bitumen exists in this coal. And every one must see, that its composition is such as would make it one of the finest coals ever discovered, could it be found in sufficient quantity.

If the hypothesis above advanced be true, there would result as an inference, a probability, that, by boring into the sandstone in the bed of the river at the highest part of the arch, a bed of coal might be discovered. And since the span of that arch is so limited, it seems hardly possible, that the

* Richard E. Taylor Esq. has recently described a genuine vein of bituminous coal of considerable extent, near Havanna, in the island of Cuba. His analysis of this coal is as follows,

| | |
|---|---|
| Volatile Matter, (gas &c.) | 63.00 |
| Carbon, | 34.97 |
| Ashes and cinder, | 2.03 |
| | 100.00 |

*Philosophical Magazine, 3d series Vol.* 10, *p.* 160.

upheaving power can be situated more than 100 or 200 feet below the river: that is, the trap rock, the supposed disturbing cause, would probably be struck before that depth were reached; and since the coal, if it exist, must lie above the trap rock, this would be reached. Whether the probability of finding a bed of workable coal is strong enough to justify the expenditure of a few hundred dollars in such an exploration, others concerned can now judge as well as myself.

### *Useless Search for Coal.*

When we consider the great economical value of coal, it is no wonder that it should be sought after with great avidity. But it is to be regretted that so many unreasonable expectations of finding this substance prevail in many parts of the State, where a slight knowledge of the geology would enable any one to decide with absolute certainty that no coal exists. It may be stated with a good deal of confidence, that the graywacke formation in the eastern part of the state, and the sandstone on Connecticut river, with the range of imperfect mica slate extending from the mouth of Merrimack river to the south part of Worcester county, are the only portions of the state where coal will ever be found; and even in respect to the last named rock, it would be unreasonable to expect in it coal of much economical value. It is possible, I grant, that some of the dark colored slates of Berkshire County may contain anthracite, allied to plumbago; but very probably all their carbonaceous matter will be found to consist of plumbago: and it would be extremely injudicious to make any expensive researches in that county for coal. Indeed, the same may be said in respect to every part of the state except the valley of the Connecticut and the graywacke region of the eastern part of the state. Yet in almost every part of the commonwealth, besides those just named, I have found respectable men so confident that coal exists in their vicinity, that every effort of mine to convince them to the contrary, seemed only to increase their confidence in their opinion. In some cases it is easy to see how a person unacquainted with rocks is deceived. In Dedham, for instance, I noticed that in digging wells, it was common to strike upon a disintegrating trap rock, which considerably resembles the bituminous shale that encloses coal; and I found that the proprietor of one of these wells, which was originally commenced only for getting water, had been carrying it deeper in search of coal: and he appeared to be perfectly confident of finding it, by pushing the excavation deeper; which he intended to do ere long; and it seemed to me that all my endeavors to convince him that his labor and money would be lost, only strengthened his opinion. And yet granite and trap

were the only rocks visible in that vicinity! Coal was to be found in rocks which have most assuredly been once in a melted state!

A tradition has long existed that the Indians were acquainted with a locality of coal near Monument mountain in Great Barrington: and a few years since, a descendant of these natives, from the western part of the country, was induced to return thither in order to point out the spot where this treasure was concealed. He professed, however, to take offence at something and departed without making the disclosure. I think that I have been more fortunate, and have discovered the spot, without either an Indian or a mineral rod. At the eastern foot of Monument mountain, in an open pasture, lie, one or two large fragments of rock, containing *schorl:* a mineral exactly resembling coal in appearance: but which is not only not coal, but a certain indication that the rock in which it occurs does not contain coal. For it is a crystalized mineral, found only in the older rocks, and never in the coal formation. Yet this is the substance, which being discovered a few years ago at the mouth of Kennebeck river, led to the announcement in the newspapers that a rich mine of coal had been found there: and I doubt not but it formed the foundation of the tradition respecting coal at Monument mountain. Surely I cannot conceive what other appearance there could have given rise to such a story. For the mountain itself is composed of granular quartz, and all the region around is as unlike a coal region as it well can be: nearly as much so as a region of trap and granite.

It ought to be remarked, however, that anxious as our citizens are to find coal within our borders, and confident as many of them are that it exists around them, scarcely no expense has been incurred in useless excavations. And it is sincerely hoped that enough of geological knowledge is now diffused through the community, to prevent any of those extravagant enterprises of this kind, which have proved ruinous and ridiculous in other parts of the United States.

A year or two since it was stated in the public papers, that a rich deposit of coal had been found in Montague nearly opposite the mouth of Deerfield river. Appearances are indeed as promising at that spot, as almost any where in the valley of the Connecticut, the rock being shale resembling that which accompanies coal. And some of it is glazed with carbonaceous matter: and this is in fact the supposed coal. But having subjected some of it in an open platinum vessel to the heat of a strong furnace for 2 1-2 hours, it lost only 6.7 per cent. leaving 93.3 per cent. of matter absolutely incombustible! It is by no means impossible that a good bed of coal may be found at this place: but the preceding statement shows that it has not yet been discovered.

## *Peat.*

Taking the state as a whole, peat is but little used, either as fuel or manure; though most employed for the latter purpose. Yet for both purposes its use is rapidly increasing, especially in the eastern part of the state, where fuel is more expensive. In view of its importance, I have made some efforts to ascertain its probable amount in our swamps. But this is very difficult; both because our swamps, where it occurs, have been but slightly explored, and because much is called merely mud, that deserves the name of peat. Several gentlemen, however, to whom I addressed inquiries on this subject, in different towns, have ventured to give an opinion as to the thickness of the beds, and the number of acres of peat found there. The following statement embraces nearly 50 towns; though by no means all in which I know peat to exist. But my object, at this time is to give data for forming an approximate estimate of the amount of this deposit in the state.

Besides the towns mentioned in the table, appended, I am sure of its existence in the following places: and I doubt not but I might add nearly every town in the State. It exists in Seekonk, Uxbridge, Col.assett, Medfield, Walpole, Wrentham, Dovers, Framingham, Sudbury, Topsfield, Ipswich, Pittsfield, Leverett, Hadley, Sunderland, Shutesbury, Lancaster, Hopkinton, Medway, Stoughton, Boylston, Reading, Milton, Needham, Billerica, Bedford, Waltham, Watertown, Action, Danvers, Chelmsford, Hamilton, Tisbury, Chilmark, Yarmouth, Brewster, Orleans, Eastham, Wellfleet, Truro, Provincetown, Falmouth and Barnstable.

| TOWNS. | Thickness of the Beds. | Acres covered by Peat Swamps. | Use. | Authority. |
|---|---|---|---|---|
| Andover, | 1 to 8 feet. | More than 2000. | Fuel & manure. | Alonzo Gray. |
| Athol, | 2 to 3 feet. | Swamp 2 miles long, 80 rods wide, (300.) | Scarcely used. | Alden Spooner. |
| Abington, | Abundant. | | | Thom. H Perry. |
| Amesbury, | 10 feet, sometimes. | 100 acres at least. | Little used. | Patten Sargent. |
| Barnstable, | 15 feet, sometimes. | 200 acres. | For fuel only. | |
| Buckland, | 1 swamp 30 ft. deep of mud. | 50 acres swamp. | | Silas Smith. |
| Bellingham, | 3 to 8 feet. | " Probably 5 or 6 acres." | | John Cook, 2d. |
| Bernardston, | | 30 to 40 acres, much peat. | Manure only. | H. W. Cushman. |
| Bridgewater, | Extensive beds. | | Fuel & manure. | P. Leach. |
| Concord, | 2 to 8 feet. | 500 to 700 acres. | do do. | Cyrus Stow. |
| Carver, | 8 to 10 feet of mud in swamps. | 500 to 800 acres bog swamps. | Not used. | John Savary. |
| Chilmark, | Various. | Perhaps 100 acres. | | |
| Dennis, | 1 to 4 feet. | 100 to 200 acres. | Fuel. | L. Nickerson. |
| Dighton, | Plenty. | | Not much used. | |
| Duxbury, | 2 to 20 feet more. | Abundant. | Fuel & manure. | G. Bradford. |
| Eastham, | 2 feet to unk. depth. | do. | | George Collins. |
| Falmouth, | 10 to 15 feet. | 20 to 30 acres. | Manure. | Wm. Parker. |
| Groton, | 5 to 20 feet. | Hundreds of acres. | Manure chiefly. | J. Green |
| Hingham, | 2 to 6 feet. | 50 to 100 acres. | | Henry Cushing. |
| Halifax, | 2 to 10 feet. | 100 to 200 acres. | Begin. to be used. | J P. Thompson. |
| Hanson, | 1 to 10 feet. | 1000 acres. | Fuel & manure. | F. P. Howland. |
| Hanover, | Rather abuundant. | | Lately used. | A. G. Duncan. |
| Holden, | Not abundaut. | | Manure only. | John Chaffin. |
| Kingston, | 2 to 10 feet. | Many Swamps. | Manure. | Asaph Holmes. |

| TOWNS | Thickness of the Beds. | Acres covered by Peat Swamps. | Use. | Authority. |
|---|---|---|---|---|
| Lunenburg, | Inexhaustible. | 100 acres. | Not used. | |
| Longmeadow, | | Perhaps 10 acres. | | |
| Ludlow, | 12 to 15 feet. | 50 acres. | Manure. | H. W B. Alden. |
| Lynnfield, | 10 to 12 ft. sometimes. | 100 to 200 acres. | | William Perkins. |
| Methuen, | 3 to 6 feet. | More than 50 acres. | Fuel. | Stephen Parker. |
| Millbury. | 3 to 10 feet. | Extensive beds. | Fuel. | Asa H. Waters. |
| Natick. | 3 to 6 feet. | 500 acres tested, 300 to 400 more | do. | Chester Adams. |
| Oxford. | 4 to 12 feet. | Several hundreds. | | Stephen Davis. |
| Nantucket. | 1 to 14 feet. | 985 acres. | | Jared Coffin. |
| Randolph, | 1 foot to a great depth. | | Fuel chiefly. | Zenas Frnch, Jr. |
| Rowley, | 3 to 6 inches. | More than 500 acres. | | |
| Roxbury, | 30 inches average. | | Manure chiefly. | A. A. Hayes. |
| Spencer, | 2 to 30 inches. | 1000 to 2000 acres. | Fuel. | Jonas Guilford. |
| Southborough, | Thick. | 500 acres. | Fuel and manure. | Joel Burnet. |
| S. Reading, | 3 feet average. | 200 acres. | | Lilley Eaton. |
| Weston, | 10 feet and less. | Numerous Swamps. | Manure. | A. Bigelow, Jr. |
| Wales & Holl'd | 4 to 10 feet. | 200 acres. | do. | E. G. Fuller. |
| Wilmington, | "Two cuttings deep." | "Some hundreds." | Fuel. | Silas Brown. |
| Westford, | Abundant. | | | Julian Abbott. |

It will be seen, that scarcely any towns, in the four western counties of the state, are mentioned above. This is partly explained by the fact, that fuel is more plenty there than in the eastern counties, so that public attention has never been directed so much to our fossil resources. But I think it undeniable, that the amount of good peat in the western counties is much less than in the eastern. Although perhaps the swamps abound as much in vegetable matter, that would be useful in agriculture, yet it does not seem to be converted into genuine peat, though I doubt not that it will be easy to find a large amount of it when there is a demand for it. Excluding these western counties, and taking the amount of peat given in the above statement as a fair average of its quantity in all the towns of the other counties, (excluding the large towns,) it would follow, that 80,000 acres, or 125 square miles, are covered with peat in that portion of the state, having an average thickness of 6 feet 4 inches. This area and depth would yield not far from 121 millions of cords. If this should be thought by any to exceed the quantity of good peat existing in that section, I presume no one will consider it too high an estimate of the amount of swamps filled with vegetable matter. I presume it falls far short of the true amount. And we hence get an enlarged view of the quantity of matter in the state that may be employed as fuel, or in agriculture, that has hitherto, except in some limited districts, remained almost untouched. It is true, that peat is not so convenient and agreeable a kind of fuel as good wood or coal; yet it certainly answers a very good purpose, and the facts in the case tend to allay the apprehension, which must sometimes rise in the mind of one who sees, in the gradual diminution of our forests, a future check to our prosperity and population. It is gratifying to learn, from so many towns, that the inhabitants are awaking so much to the

use of peat and peaty matter. Some gentlemen have even spoken of it as a "peat- fever." I hope it has not yet reached its crisis.

## VII. ROCKS AND MINERALS FOR ARCHITECTURAL AND ORNAMENTAL PURPOSES.

I bring under one head the two objects of architecture and ornament, because they are so intimately connected that it is not easy to separate them. Very little use, however, has yet been made of our mineral resources for mere ornament: but for the purposes of construction, they have been very extensively employed.

### 1. *Granite and Sienite.*

Much confusion has arisen in the application of these terms. They were originally applied to designate rocks very different, if not in composition, yet in their geological relations. But most of the rock that is generally described as sienite, is a variety of granite. This is certainly the case in Massachusetts. Wherever the granite admits hornblende into its composition, I have considered it as a sienite; and not unfrequently the hornblende constitutes the principal ingredient; taking the place, more or less, of the quartz and mica, so as to form a compound of hornblende and feldspar. This compound forms some of the most beautiful varieties of sienite, though extremely hard to work, for architectural purposes. But not a little granite that contains no hornblende goes by the name of sienite. Thus, much of the Quincy granite is wanting in hornblende; but being almost destitute of mica, and having the close aspect of sienite, it is called indifferently by either name.

The variety in the composition, color, and hardness of these rocks in Massachusetts, is almost endless. The quartz and feldspar are commonly white, yellowish and gray: the latter not unfrequently flesh colored: the mica is very often black, but sometimes of a silver color. When the quartz prevails, the rock is easily broken, but hornblende renders it tough. The predominance of feldspar generally gives the rock a more lively white color and renders it rather easier to work. But I shall not attempt to describe particularly all the varieties of these rocks that occur in the State. An inspection of the specimens which I have collected, will at once give an idea of the kinds obtained at the principle quarries, and of numerous other varieties which I have met with in different localities. (Nos. 1271 to 1348, and 1410 to 1458, also 2395 to 2477.)

The very coarse varieties of granite, which are found in some parts of the State, do by no means furnish a good building stone: indeed, some of them hardly serve for common walls. Much of granite in the vicinity of Connecticut river, is of this description; as also a considerable portion of that forming beds in gneiss, which extends from Southboro' to Andover. But most of the granite in the eastern part of the State, is of so fine a texture, as to answer admirably for architecture and other economical purposes. Along with sienite, it extends around Boston, running in a curvilinear direction, at the distance of fifteen or twenty miles. From Cohasset to Quincy, at the southern extremity of the curve, and from the end of Cape Ann to Salem, on the north, the formation is most fully developed, and is there quarried extensively. The Quincy quarries are probably the best and most generally known; and few citizens of the State are unacquainted with the rock thence obtained, now so extensively used in Boston and elsewhere. The quantities which those quarries (or rather mountains) will furnish, are incalculably great. One railroad, as is well known, has been used for several years to convey the granite from the quarry to Neponset river, a distance of three miles. It is thought, however, that the granite has not reached its *minimum* price. Yet even now, Boston is almost as much distinguished for its granite structures, as the metropolis of the Russian Empire.

Some of the granite obtained on the north of Boston, cannot be distinguished from that of Quincy. I observed the resemblance most strongly in Danvers and Lynnfield. At the former place it is quarried, and fine blocks are obtained. Extensive quarries are also opened in the north side of Cape Ann, in Gloucester, as well as at the Harbor. The rock here resembles that of Quincy; but it is generally harder and of a lighter color. At these quarries no railroad (except one of a few rods in length) is necessary to transport the rock to the sea-side: since vessels can approach very near the spot. And, since the demand for this rock must increase, in our country, for many years to come, and Cape Ann is little else than a vast block of it, it seems to me that it must be regarded as a substantial treasure to that part of the State,—far more valuable than a mine of the precious metals. At Squam, in Gloucester, I was informed that blocks of granite had sometimes been split out sixty feet in length; indeed, I saw the face of a ledge from which they had been detached. At Pigeons Cove a mass was detached 100 feet long and 4 feet thick.

At Fall River, in Troy, which lies upon Taunton river, are other extensive and interesting granite quarries. This granite, as the Map will show, is connected with the Quincy range above described. Yet the greater part of the granite in Plymouth and Bristol is coarser than that of Quincy and Gloucester, and more liable to decomposition. But no rock can be finer for

architectural purposes than the granite of Troy; and immense quantities have been obtained from this locality. The large manufactories at Fall River are built of it, as is also Fort Adams at Newport, Rhode Island. The feldspar of this rock is a mixture of the flesh red and light green varieties; the former predominating: the quartz is light gray, and the mica, usually black. It works easily, and has a lighter and more lively appearance than Quincy granite. Blocks of this granite have been split out from fifty to sixty feet long, as a sign-post at one of the former public houses at Fall River, will attest: it consists of a single block. The contiguity of this granite to water transportation, will always render it peculiarly valuable.

The granite range extending from Cohasset and Quincy, through Randolph, Stoughton, Foxborough, &c. nearly to Rhode Island, affords much valuable stone for architectural purposes: and it is wrought more or less in every town through which it passes.

The branch of this extensive deposit of granite, which is fully developed a little south-west of Dedham, furnishes some beautiful varieties of stone. No better example can be referred to, than the elegant pillars of the Court House in Dedham. This granite is very fine grained, and so white, that at a short distance it cannot be distinguished from white marble. The pillars just named were obtained near the dividing line between Dover and Medfield, where vast ledges of excellent stone occur.

The stone used in Boston under the name of Chelmsford granite, is found in a range of this rock, not connected with the deposit that has been described above. Nor does it come from Chelmsford; but from Westford and Tyngsborough. In the latter place, it is obtained chiefly from bowlder stones; but ledges are quarried in Westford. I do not know why it has been called Chemlsford granite, unless from the fact that large quantities are carried to Lowell, (formerly a part of Chelmsford,) to be wrought. This rock is pure granite, with no hornblende; and being homogeneous and compact in its texture, it furnishes an elegant stone. Good examples of it may be seen in the pillars of the United States Bank, and in the Market House in Boston. These were from Westford.

Four miles north of Lowell, a quarry of this granite has been opened in Pelham, N. H. Blocks may be obtained from this place of any length under thirty feet. It is a very fine variety, is much used, and appears superior to the Chelmsford granite.

The Westford and Pelham granite is connected with an imperfect kind of mica slate, in which it seems to form beds, or large protruding masses. At Fitchburg, a little south of the village, is a large hill of the same kind of granite. This is quarried though not extensively, on account of the little demand for the stone. This single hill 300 feet high, and nearly a mile in

circumference at its base, might furnish enough to supply the whole State for centuries. And there is needed only better means of transportation to bring it into extensive use.

The manner in which the granite is usually split out at the quarries is this. A number of holes of a quadrangular form, a little more than an inch wide, and two or three inches deep, are drilled into the rock, at intervals of a few inches, in the direction in which it is wished to separate the mass. Iron wedges, having cases of sheet iron, are then driven at the same time, and with equal force, into those cavities; and so prodigious is the power thus exerted, that masses of ten, twenty, thirty, and even fifty and sixty feet long, and sometimes half as many wide, are separated. These may be subdivided in any direction desired; and it is common to see masses thus split, till their sides are less than a foot wide, and their length from ten to twenty feet. In this state they are often employed as posts for fences.

Respecting the price of the granite from the quarries that have been described, I have not been able to obtain much information. At Fitchburg, I was told that it was sold at the quarries, well dressed, at forty cents the superficial foot; and at Squam at forty-five cents.

The cost of hammering and fine dressing granite in Boston, in the style of the Tremont House, I have been credibly informed, is about thirty cents the superficial foot. Ordinary work, however, is from twenty-five to thirty cents; and not unfrequently, even as low as twenty cents.

Posts for store-fronts cost about thirty-four cents per foot in Boston. The columns of the Hospital were obtained for about one dollar per foot.

To show how rapidly the price of granite has fallen, I would state on the authority of a respectable architect in Boston, that the cost of the blocks of the Quincy granite for the Bunker Hill monument, delivered at Charlestown, in a rough state, was thirteen cents, three mills, per foot; and the cost of the unhewn stone for the church built in the year 1831, in Bowdoin street, Boston, was fifteen cents: but six years before, the rough Quincy granite, for the United States Branch Bank, cost two dollars per foot.

I have now given an account of the most extensive and important quarries of granite and sienite in the eastern part of the State. Granite is wrought more or less, however, not merely in all the towns through which its ranges pass, but also in other places, in their vicinity; large blocks of it having been removed thither by diluvial action in former times.

Although the granite in general, in the vicinity of Connecticut river, is too coarse for architectural uses; yet in Hampshire county are several beds of a superior quality. Perhaps the best is found in Williamsburgh, a few miles from Northampton. This rock, (some of which may be seen in the front of a few buildings in Northampton,) and in the mansion of the Hon. James

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Fowler in Westfield, very much resembles the granite found in the vicinity of Dedham, and yields in beauty and value to none in the State. It exists in abundance in Northampton, Whately, and Williamsburgh; but nas yet been quarried only on a very limited scale.

On the east side of the Connecticut, a very beautiful sienitic granite exists in Belchertown; in which the mica, when the hornblende is wanting, is very black. It is not surpassed in elegance by any rock in the State; but it has not as yet, to my knowledge, been quarried at all. Indeed, very little real granite is employed in the middle or western parts of the State, except in a rough condition.

This sketch of the granite of Massachusetts, although brief, is sufficient to show that we have a great number of varieties, and an exhaustless quantity of this most valuable material for durable and elegant architecture. Numerous varieties not mentioned above, which have fallen under my consideration, either in ledges or loose blocks, will be found in the collection of specimens; and some of these are peculiarly beautiful. Numerous other varieties have doubtless escaped my observation. Indeed, we may safely assert, that no part of the world is better furnished with this useful and indestructible rock.

### 2. *Porphyry.*

This term, as it is employed in the arts, embraces several varieties of rock not designated by its strict geological sense. Although upon the Map, I have included in the term, only the porphyry of geologists, yet in this place, I shall describe all those compounds occurring among us, which have been denominated porphyry in the arts.

The first and most extensive of these, is the genuine feldspar porphyry, represented on the Map in large quantities in the towns of Medford, Malden, Chelsea and Lynn, on the north of Boston; and in Needham, Milton and Braintree, on the south. This is the oldest and most enduring of the porphyries, and, indeed, the hardest of rocks. Its basis is generally compact feldspar, reduced to a homogeneous paste, and of various colors; as light purple, red of various shades, brownish black, and greenish gray. The imbedded crystals are either feldspar, or quartz alone, or existing together in the same rock; and their colors are very various, though more usually white or gray. By these mixtures porphyries are produced, rivalling in beauty the best antique porphyry. This rock is polished with so great difficulty, that it is rarely used in our country, either for ornamental or useful purposes. But it would be strange if an increase of wealth and refinement should not create some demand for so elegant and enduring a rock. Whenever this shall happen, the vicinity of Boston will furnish every variety that can be desired, and in blocks large enough for any purpose. Quite a number of

smoothed or polished specimens may be seen in the collection. (Nos. 1231 to 1269.)

The porphyry range on the north of Boston, is most perfect in its characters, and in the greatest abundance at any one place; although the southern range spreads over a greater extent of surface. In Lynn, and some other towns, I have observed blocks of porphyry that were brecciated—that is, they were composed of angular fragments of porphyry reunited. This furnishes a beautiful variety for polishing, (Nos. 1264 to 1269.)

On many of the beaches south of Boston large quantities of porphyry, sienite, and granite pebbles, are accumulated, so that a fine collection may there be obtained. The places which I can refer to with most confidence, are the head of Nantasket Beach, the northeastern extremity of Cohasset, and the beach at the foot of Manomet hill in Plymouth. In a few places, as at Hingham, I noticed that these beautiful pebbles had been collected and used for paving the alleys in front of the houses: those of different colors being arranged in a beautiful manner so as to present an elegant Mosaic. It seems to me that if some of these pebbles were polished, or only varnished, so as to exhibit their true character, they might even be employed along with sea shells for parlor ornaments. At any rate, they would ornament a geological cabinet. And I have been surprised that no lapidary has made a collection of the many elegant varieties of our granites, porphyries, and other beautiful rocks, for the purpose of selling them. If they were only cut into small specimens and polished, and arranged into a sort of mosaic, set in marble, as is done so beautifnlly in Italy, can there be a doubt but they would meet with a ready sale? Even if no other varieties were introduced than I have placed in the Government collection, such a table must be an elegant parlor ornament, and the directions which I have given, will enable an artist early to find the localities of these. But many more varieties would no doubt be easily discovered.

The beach at Manomet hill in Plymouth, is almost entirely covered with bowlders and pebbles for one or two miles in length. I passed over its whole length one summer morning in 1839, so early that the sun had not dried off the rain of the preceding night: and the colors of the specimens were brought out as perfectly as by polishing. It was equal to passing through a fine geological cabinet. It was more: for this cabinet of nature was on so grand a scale as to throw into the shade all the works of man. Were I a resident of Plymouth, I am sure I should often anticipate the morning sun in an excursion to this spot.

### *Sienitic Porphyry.*

When sienite contains crystals of feldspar imbedded in the mass, it is

said to be porphyritic; and some varieties of this rock in the eastern part of the State are very elegant. Essex county produces some of the finest specimens, particularly Cape Ann. Sometimes the imbedded crystals of feldspar, are white, sometimes flesh colored; and in Gloucester, I found a rock in which they were of a rich bronze color. These sienitic porphyries are extremely elegant when polished; but I am not aware that they are employed at all for ornamental purposes, in this country. (Nos. 1341 to 1346.)

*Porphyritic Greenstone.*

The ingredients of greenstone are often not easily distinguished from each other by the naked eye; and when, in such a case the rock contains disseminated crystals of feldspar, it becomes porphyritic. If these crystals are greenish white, and the base blackish green, the rock is the *green porphyry* of the ancients. In Dorchester, Brooklyn, and Roxbury, according to the Messrs. Danas, it occurs in rounded masses; and in small quantity, in veins, at Marblehead. But I have found it in large veins, traversing sienite at Sandy bay, on the northeast side of Cape Ann. Large blocks might be hence obtained: and if polished, it would constitute a truly splendid ornament for the interior of a church, or a private dwelling.

If the feldspar crystals be black, or grayish black, the rock is the superb *black porphyry* of the ancients. This occurs in small beds and rolled masses in Charlestown, and in veins of greenstone, at Marblehead, according to the Messrs. Danas: but I have not met with it.

The hornblende slate in various parts of the State, but particularly in the region of Connecticut river, is frequently porphyritic: and exceedingly resembles porphyritic greenstone; being, in fact, composed of the same ingredients; and differing only in its slaty structure, and in the more distinctly crystaline character of the hornblende. The disseminated crystals of feldspar are usually white. In Canton and Easton, they are sometimes the compact variety, yet retaining their form perfectly. A fine variety and in large quantity occurs in Heath, a specimen of which may be seen in the collection. (No. 944.)

In Ipswich I found a bowlder of greenstone in which are imbedded numerous distinct crystaline masses of jet black Karinthin. (No. 1159.) The same rock occurs in Durham N. H, and on the western slope of the Green Mountains in Vt. But I apprehend that the color of the rock is too dark to be employed much for ornament.

### 3. *Trap Rocks.*

All the trap rock of Massachusetts, that is of any importance in an architectural point of view, is greenstone.

### *Greenstone.*

This is one of the most enduring of rocks; but it is usually so much divided by irregular seams, into small and shapeless blocks, that it is but little employed, either in the construction of houses, or walls. Its dark color, also, renders it less acceptable than granite or limestone. Still it is beginning to be used for building houses, in its unaltered state. The irregular blocks may be so laid with white mortar, especially in the Gothic style of building, as to form a picturesque and pleasing structure. The Episcopal Church in the city of New Haven, Conn. presents a good example of this kind of architecture.

In the valley of Connecticut river, much of the greenstone is vesicular, and not well fitted for buildings. But those numerous beds of this rock that are shown upon the geological map in Worcester county, are very compact and well adapted for architecture. This rock as it exists in bowlders has such an unpromising aspect that it is usually overlooked or disregarded; as it was by me till recently. But I suspect that it may be found in some towns where no other good rock exists for building: and where it would be employed if its good qualities were known.

### 4. *Gneiss.*

This rock is commonly known under the name of granite; and, indeed, it is composed of the same materials; but in the gneiss, the structure of the rock is slaty, and it splits in one direction better than others; yet this slaty structure is often hardly perceptible, even in wrought specimens; and hence for all architectural and economical purposes, the distinction between granite and gneiss is of small importance; though of much consequence in respect to the science of Geology.

The quarries of gneiss in Massachusetts are perhaps even more numerous than those of granite, though not in general so extensively wrought. It forms admirable building stone; and is in no respect, that I know of, inferior to granite; while the facility with which it cleaves in one direction, renders it easier to get out and dress; so that it can be afforded at a less price. Accordingly we find that a large proportion of the better class of buildings in the extensive portion of the central part of the State where this rock prevails, are underpinned by wrought blocks of it. Its fissile character also, renders it an excellent material for common stone walls and flagging stones. The same property enables the quarryman to split out layers of it of almost any size, and only a few inches in thickness: and their surface is generally

so even, as to require but little dressing. Hence it is very common to see such large stones of this description in front of very many of our churches and other public buildings.

In Europe gneiss seems to have been applied to few useful purposes. A late geological writer in Great Britian, says that 'this schistose (slaty) body serves no particular purpose in the arts of life.'* Dr. Macculloch however mentions that the micaceous varieties are employed in building and sometimes for roofing.† This rock appears to be more perfectly developed in our own country than in Europe.

The western part of Worcester county, and the eastern parts of Hampden, Hampshire, and Franklin counties, afford the best quarries of gneiss. That branch of the Worcester range extending into Middlesex county, and the range in Berkshire county, do not furnish so good specimens for architecture, though by no means devoid of interest in this respect.

The quarries of gneiss that are most extensively wrought, and furnish the best stone, are situated in the following towns: Wilbraham, Pelham, Monson, Palmer, Montague, Dudley, Millbury, Westborough, Boylston, and Uxbridge. Much of the stone at these quarries can hardly be distinguished from granite, even by the Geologist. The Millbury gneiss, for instance, is very much used in Worcester, and does not there present any appearance of stratification, and very little of a slaty structure: while the granite, that is quarried in the east part of Worcester, is distinctly divided into parallel masses and would probably be called gneiss by most persons, rather than the Millbury rock.

At these gneiss quarries it is easy to obtain blocks from ten to twenty feet long, which are only a few inches thick. At Dudley, I was told that narrow slabs of this rock, such as would answer for posts or side walks, could be split out, and delivered in the center of the town for four cents per foot.

The quarries in Monson and Palmer are distinguished by one peculiarity of some importance. The strata are nearly perpendicular to the horizon, and are divided by a set of parallel seams, running horizontally, into blocks of any desired thickness, and of a width varying from one foot to four feet. This is most remarkably the case at a quarry 1 1-2 mile northwest of the center of Monson, where blocks may be got out 70 feet long. On dressing this rock the surface, from the irregularity of this laminar arrangement, and the diversified colors of the materials, becomes highly variegated, so as at a little distance to appear like clouded marble. This is a very frequent appearance in the gneiss of other localities; as in that of Millbury, Wilbraham, and Pelham; and often it is a really elegant rock. Good samples of this variegated gneiss may be seen in many of the houses and stores in Worcester, Springfield, Amherst, and : Monson: in the latter place especially in the dwelling house of Joel Norcross Esq. Upon the whole the quarry in Monson above described, which is only two or three miles from the Springfield and Boston rail road, promises the most of any in the state Beautiful sepulchral monuments are some-

* Ure's Geology, p. 100. † Macculloch's System of Geology, Vol. 2. p. 155.

times made from it. For the sake of variety at least, one of this description ought to be placed at Mount Auburn.

### 5. *Hornblende Slate.*

This rock is usually associated with gneiss, and is by some regarded as a variety of that formation. Nevertheless it is a very different rock, both in composition and aspect. I do not recollect to have seen it employed in Massachusetts for any purpose except for common stone walls. It is often, however, very fissile, and presents an even surface. And in the side walks in the city of New Haven, I have noticed good flagging stones of this rock. I presume some of the localities in Massachusetts would furnish slabs for the same use: as for instance in the vicinity of New Bedford, and in the towns of Leyden, Heath, Warwick, &c.

### 6. *Mica Slate and Quartz Rock.*

The first of these rocks has usually a structure too irregular for the purposes of construction: But sometimes it can be split into large slabs of convenient thickness; as in the range that passes through Goshen, Chesterfield, &c. where it is quarried for hearths and door stones: it being so even and smooth as not to require dressing, and being also tolerably good for bearing moderate degrees of heat. The quarries of Bolton in Connecticut, which probably furnish the best flagging stones in the United States, are in mica slate, and the rock of Goshen, &c. might be used for the same purpose, were it near a market. But the principal use of the mica slate of Massachusetts is for firestone and whetstones: and these will be described in another place.

Our quartz rock, which is usually associated with mica slate, or gneiss, is less frequently employed than mica slate for the purposes of construction. From the quartz rock of Washington in Berkshire county, very fine flagging stones are obtained. In the narrow range also, colored as mica slate, but which frequently passes into quartz rock, running across the state from Monson to Warwick, I apprehend good flagging stone exists. I would refer particularly to a hill, 100 rods east of Sedgwick's tavern in the south part of Palmer, near the Boston and Springfield rail road. None of this has been dug out: but I am disposed to believe that this hill would furnish good stone for this purpose; and not unlikely also some firestone. I shall notice in another place other localities of quartz quartose firestone as well as quartz adapted for the manufacture of glass.

### 7. *Talcose Slate.*

The greater part of this rock, or those portions of it that usually go by the name of talcose and chlorite slate, are very similar to mica slate in their adaptedness for architectural purposes. But I hardly know of their being employed except for common walls. Soapstone, or Steatite, however, is now regarded as a variety of talcose rock; and this is one of the most valuable rocks in the state, and therefore its localities deserve special description.

I am of opinion that along the Western rail road, in the west part of Chester and Middlefield, good quarries of flagstone and of building rock may be opened in the perpendicular ledges of mica slate, talcose slate, and gneiss, which crowd upon and overhang that road. Other valuable rocks occur in the same region, as I shall soon show.

#### *Steatite or Soapstone.*

This is the softest of all the rocks employed in architecture. This property, rendering it easy to be sawed or cut without injuring an edge tool, and

its greasy or soapy feel, are such striking characteristics of this rock, that most people are acquainted with it. It is sometimes called *potstone*, and sometimes in this country, *freestone*. It is composed mostly of talc.

Next to the ease with which it may be wrought, its great power in resisting heat, is the most valuable property of this rock. Hence it is extensively employed for fire places and furnaces.

It is also turned into crucibles and small furnaces for culinary use. Inkstands are made of it in great numbers, and various other articles. As it hardens in the fire, it is used in Europe for imitating engraved gems. It has been employed in various countries as a substitute for soap and fuller's earth. Spanish and French chalk are varieties of steatite. Savage nations are said to mitigate hunger by eating this soft mineral; as however it contains nothing alimentary, it can act only as a palliative of hunger.* Those varieties that are most infusible are employed in England extensively in the manufacture of porcelain.

Steatite, like serpentine, usually occurs in beds of no great extent. They are numerous in Massachusetts, and very commonly they are associated with serpentine, or in the vicinity of it. This is the case in the northeast part of Middlefield, where one of the finest beds of it, in the State, is found: although it contains small masses of *bitter spar*, which renders it less easy to work. But this quarry has been explored more extensively than any other in the State; and the blocks transported to Northampton, and even to Boston. In Windsor are not less than three beds of this rock, from which the New Lebanon Shakers obtain it, for converting into inkstands. I found a small bed of it in Cheshire, one mile east of the Four Corners in the gneiss formation. Another occurs in Savoy; one in Hinsdale; one also in Blanford, which is wrought and produces an excellent stone. Two beds occur also in Granville. Another is opened in Zoar, where are two distinct varieties, one nearly white, another of a deep green. In Rowe is another quarry, where these two varieties are equally distinct. At the two last named localities, however, the rock is distinctly green and white talc; and indeed, the two minerals (talc and steatite) are probably in every case identical.

In the west part of Chester, near the Western rail road, and about a mile from where Henry's tavern was formerly kept, is a bed of considerable extent, between talcose and hornblende slate, and associated with serpentine. It has been wrought on a small scale, and may probably prove very valuable from its proximity to rail road. I am told that this same bed appears a mile or two farther north, on the east side of the river, towards Middlefield.

On the east side of Connecticut river are several beds of this rock, more or less quarried in every instance; but in general not explored deep enough to develope the rock in its unaltered character; for the air and moisture generally affect it for several feet deep. In the south part of

* See Brongniart's Mineralogy.

Shutesbury is one bed: in the southwest part of Wendell another; and two miles east of the center of New Salem, a third. In the west part of Petersham, a fourth. The quality of the rock at these places, is not as good as that west of the river; though it has scarcely been explored at all, at the localities above mentioned.

In Groton is a bed of soapstone on which considerable labor has been expended. Its width appears to be 10 or 12 feet, and it descends into the earth towards the southeast; dipping about 30°, and lying between layers of mica slate. It is of good quality, and its proximity to Boston, Newburyport, and Salem, will probably render it an object of importance.

A bed of soapstone has recently been discovered in Worcester; and the specimens thence obtained, (Nos. 403 and 1548,) show it to be more elegant in appearance than any other in the State. The bed has yet been penetrated only about five feet: but should it prove extensive, its situation so near the Blackstone Canal, will render it an object of no little importance. It is not now wrought.

In digging a well near the center of Millbury, a year or two since, a mass of soapstone of a rather peculiar character was penetrated: but it is not now accessible. In the same region, several years ago, in digging the Blackstone Canal, a variety was obtained, which, on being thrown upon hot coals, shot out into vermiform masses, which very much resembled living worms. It was for a time called vermiculite: but the name is very properly abandoned.

No. 2506 is a specimen of laminated green talc from Fitchburg. I am told that the bed is four feet thick, and most of it of a much finer grain than this specimen. A smaller specimen sent me is nearly compact. If enough of either kind can be obtained, free from foreign minerals, there is no doubt but it may prove valuable.

An interesting and important locality of this rock, is in the east part of Andover, four miles from the Theological Seminary. The bed lies in hornblendic gneiss, whose stratification is very irregular and indistinct; but I ascertained its direction to be almost N. E. and S. W. and its dip large, corresponding in both respects with the great deposit of gneiss extending diagonally across the state. The bed is not less than 50 feet thick; and has been opened by the proprietors, Flint, Jenkins & Co., several rods in length. They have wrought it for a variety of purposes, and it admits of being smoothed so as to appear well. Its composition is remarkably uniform, consisting essentially of rather hard foliated talc, though occasionally a black mineral is disseminated through it, which appears to be hornblende. Its strength appears to be greater than marble; as the proprietors informed me that a square piece 2 inches thick, laid on two supports 18 inches apart, sustained 800 pounds, laid upon a spot in the center only half an inch wide; 860 pounds broke it.

The specimen No. 2507 gives no idea of this rock, except as it is newly broken from the quarry. The proprietors, however, inform me, that one or two monuments made from it, have been placed at Mount Auburn. And for such a purpose it seems well adapted. I cannot but believe that this rock, which is certainly a peculiar one, and quite different from ordinary soapstones, will ere long come into extensive use, and the enterprizing proprietors be rewarded for their expense and perseverance. It seems applicable to nearly every use for which marble is employed.

Large bowlders of this rock are scattered over a considerable space around the quarry, in an east and west direction, , and since the diluvial current in this region was from the north, these bowlders render it probable that the bed is far more extensive than the spot which is opened; or that other beds occur beneath the surface.

In the southern parts of New Hampshire and Vermont, as at Francestown in the former, and at Windham and Grafton in the latter, are fine beds of this rock: and I am told that at present the shops in Boston are generally supplied from those places. But as better means of transportation are opened with the interior of the state, it is hoped that some of the extensive beds existing in our mountains will be explored. It is a substance that must always be in demand; and al-

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though capitalists may not expect very large returns from such investments, they can hardly fail of being safe, if the beds be carefully explored before they are opened.

## 8. *Serpentine.*

In New England serpentine is almost universally associated with steatite, either in talcose slate or gneissoid rock. And although generally regarded in Europe as an unstratified rock, in this country it belongs rather to the metamorphic class. But these points belong to the scientific rather than to the economical part of my report.

In richness and variety of colors, serpentine exceeds all other rocks; and is, therefore, eminently suited for ornamental sculpture and architecture. The prevailing color is green, of different shades, spotted or clouded, or veined with other colors; and hence its name, from its spotted and striped appearance, bearing a resemblance to the skins of some serpents. In hardness it varies very much; being in some instances very hard, and in others, as easily wrought as marble.

This rock exists in Massachusetts in great abundance, particularly in the Alpine part of the State, or in the Hoosac mountain range. The most extensive bed occurs in Middlefield, in the southern part of the town. This bed cannot be less than a quarter of a mile in breadth, and five or six miles long. The colors of the rock are various, and its hardness unequal. If wrought it might supply the whole world. It yields both the precious and the common varieties. There is another bed in the same town, associated with steatite or soapstone. In the west part of Westfield is found another extensive bed of this rock, extending into Russell, of a much darker color, and containing green talc. This has been used in a few instances for ornamental architecture, and has a rich appearance when wrought. Three beds of serpentine are found in Blanford, and another in Pelham, in the southwest part of the town. The color of this last is quite dark, and the quantity of the talc is considerably large. A large bed occurs in connection with soapstone, on the north side of Deerfield river, in Zoar, near the turnpike from Greenfield to Williamstown. Specimens from this place resemble those from the celebrated localities of this rock at Zobilitz in Saxony. Serpentine also exists at Windsor in two beds; and there is an immense bed of it in Marlborough, Vermont, and another still larger in Cavendish; as also in several other towns in the southern part of that State.

I do not doubt but many more beds of serpentine may be found in the broad mountainous range lying west of Connecticut river: for this rock is by no means apt to arrest the attention, and has indeed a forbidding and desolate aspect where it has been exposed to atmospheric agencies. In some of my most recent excursions to that region, I have discovered two new beds, not mentioned above. One is in the gneiss formation that shows itself a mile or two east of Cheshire four corners. A large amount of serpentine evidently exists here: but the extent of the bed is concealed by the diluvial detritus. The other bed is in the west part of Chester, associated with steatite, on the high mountain west of Westfield river. These two rocks lie between hornblende slate on the west, and talcose slate on the east, and extend southerly at least into the lofty mountain south of the southwest branch of Westfield river, and probably in a northerly direction quite as far. But as the serpentine is an object of no interest to any but the geologist, its extent has never been traced out. I have every reason to think, however, that both the steatite and the serpentine are associated, perhaps as a continuous bed, with the talcose slate nearly across the whole of Massachusetts.

A locality of noble or precious serpentine has long been known to exist in Newbury, two and a half miles south of Newburyport, at an abandoned lime quarry, called the Devil's Den. Only small masses can be here obtained: but when polished, they will compare with any in the world for beauty. (Nos. 870 to 873.)

When limestone is mixed with serpentine they constitute the famous *verd antique marble*; of

which such extensive beds occur near New Haven in Connecticut. Some of the specimens at Newbury are of this description; and more beautiful than that in Connecticut. Specimens are also common in the serpentine of Westfield; and in the west part of Middlefield. I have lately found a very delicate variety in the most easterly bed of limestone in that town. The limestone is hard and compact, of a white color, and the serpentine is of a delicate green, forming however but a small part of the mass. When polished it presents an agreeable aspect. (Nos. 1954. 1955.) It is doubtful whether large blocks could there be obtained. But both there and at Newbury pieces might be got out that would answer for small ornamental articles of great elegance.

A remarkably interesting bed of serpentine has been recently discovered in the town of Lynnfield, near the center of the place, where a quarry has been opened. The proprietor, Mr. James C. Nichols, informs me that he has traced the bed in a north-east direction from this spot two or three miles. Where it crosses the county road leading from North Reading to Salem, about a mile and a half from the quarry, a large quantity was blasted out, which was too hard to be wrought without great difficulty. The bed has not been traced far to the south-east of the quarry, as the rocks are mostly concealed by diluvium. But the great quantity of serpentine blocks scattered in a rather south-west direction for two or three miles, show that it does extend that way a considerable distance: while their great number gives us a striking idea of the extent of the whole bed. There can be no such thing as exhausting it. Its width in some places is not less than nine or ten rods.

From the direction of this bed of serpentine, as well as the character of the diluvium, I am satisfied that it is embraced in the great gneiss formation whose strata run from north-east to south-west across the state. Probably the bed is not far from the eastern limits of this formation.

When first quarried, "this serpentine is much softer," says the proprietor, "than any marble I have seen. It can be cut with a handsaw, or turned in a lathe, nearly as easy as *lignum vitæ;* but while in this soft state it will not receive so high a polish." The specimen No. 2182, which was polished and presented to the state collection by Mr. Nichols, will give an idea of common specimens of this stone. He says that "this serpentine can doubtless be wrought with less expense than common marble. We have made but a small opening, yet we have obtained some sound slabs five feet in length: and we shall doubtless find the stone sufficiently sound to afford slabs large enough for any ordinary purpose. We have not manufactured much of the stone, nor offered any for sale: yet we have full confidence that it would find a ready market."

Should it prove that this serpentine could be afforded at a cheaper rate than marble, I cannot see why it must not come into extensive use in all cases where a stone of a dark shade is preferred; though there will doubtless be found on exploration, pieces of various shades. The situation of the quarry so near the sea-board, and in proximity with several of the largest towns of New England, is an additional reason why I look upon this discovery as one of much promise.

Considering the extent and variety of serpentine in Massachusetts, it seems not a little surprising that no efforts, or next to none, have been made to use it for ornamental or architectural purposes. In Europe, it is employed for trinkets, vases, boxes, chimney pieces, and even columns of large size. In Spain, it is said that churches and palaces abound with columns of this description. If ever the serpentine of Massachusetts shall be extensively wrought, I doubt not that specimens will be obtained, rivaling the finest varieties of Europe. It is not at present easy to obtain hand specimens, that shall give a fair representation of this rock, because it is injured to a considerable depth, from the surface by exposure.

The composition of serpentine is regarded as an object of some economical importance, because valuable salts may be manufactured from it. I have therefore subjected a few of our serpentines to analysis; and the results are given in the following table.

| No. | LOCALITY. | Magnesia. | Silica. | Peroxide of Iron | Water. | Loss. |
|---|---|---|---|---|---|---|
| 870 | Newbury, precious. | 42.18 | 38.65 | 2.81 | 15.46 | 0.90 |
| 874 | Chester, common. | 44.91 | 34.91 | 10.27 | 9.45 | 0.46 |
| 879 | Blanford, do. | 40.19 | 38.09 | 6.75 | 14.77 | 0.20 |
| 893 | Westfield, do. black. | 33.74 | 43.03 | 8.88 | 13.93 | 0.42 |
| 2182 | Lynnfield, do.* | 42.00 | 37.00 | 2.00* | 15.00 | 4.00 |

The magnesia is the ingredient in serpentine that may be, perhaps, made of some economical value: and this seems, according to the above analysis, to be present in large quantity: By means of sulphuric acid this may be converted into sulphate of magnesia, or Epsom salts; and these by means of a carbonated alkali, may be changed into carbonate of magnesia; one of the forms in which this substance is sold in the shops. Whether such a manufacture would be profitable, I am unable to say. But I am sure that if such a process should be undertaken, Massachusetts can furnish enough of the material for all future generations and the whole world.

By comparing the present with my preceding reports, it will be seen that since the first one was published, I have discovered many beds of steatite and serpentine: And yet I have taken no special pains to find them: but have fallen upon them as it were accidentally; while pursuing the general objects of the survey. The announcement of deposits of such rocks, hitherto unknown, will not I am aware excite any interest in the community. Yet I cannot but regard every such discovery as adding a valuable item to our mineral wealth: for substances of this kind must come gradually into use as a country grows older and more wealthy: and when once brought into the market, the demand for them will never cease. Posterity, therefore, may be benefited by the new facts which I here present, if the present generation are not.

## 9. *Limestone.*

All rocks must yield in economical value to limestone. Its importance in agriculture I have already considered. But as a common building stone, as marble, and as forming the basis of several kinds of mortar, it still remains to be described.

Wherever limestone is abundant enough to be employed for making walls,

* Analysis by Dr. Charles T. Jackson.

it is one of the cheapest and best of all rocks. It is more easily wrought into proper shape, because softer, is less likely to be too fissile, and its appearance is better than most other stones. Hence it is sometimes employed in its undressed state for the walls of dwelling houses and factories: as at North Adams.

When, however, limestone is free enough from fissures and compact enough to admit of a good polish, so as to be employed as marble, it becomes still more valuable. A large proportion of the limestone in Berkshire county is of this description: but scarcely any attempt has been made to obtain marble from any other limestone bed in the state. It was formerly hoped that the bed in Stoneham would furnish even the rare variety used in statuary. And indeed, in small specimens it will compare advantageously with the famous Carara marble, so extensively employed for statuary: But it is said that it is so full of fissures that blocks large enough for that use cannot be obtained. Whether the bed has been explored far enough to settle this point, I am not prepared to say.

The best of the Berkshire marbles are white; most of them of snowy whiteness. Some of them, however, are clouded; and very frequently they are gray. The gray and the white are the most esteemed for durability. And it is this property that gives to these marbles, for the most part, their greatest value; although they admit of a fine polish, and for primary marbles, are very elegant.

In regard to the chemical constitution of these marbles, I find from numerous analyses, which I have made, that although magnesian limestones are very common in Berkshire, the best marbles are almost wholly free from magnesia. The beautiful clouded marble of Great Barrington is an exception; containing 38 per cent. of magnesia: and I have seen a few specimens of very fine white dolomite, that admitted of a beautiful polish: and in fact, formed as elegant a marble as I ever saw. (No. 1925.) But in general I do not doubt but magnesia is unfriendly to the firmness and durability of marble; as indeed chemical principles would lead us to expect. But more of this in another place.

The great and increasing demand for the marbles of Berkshire out of the state, and their high character abroad, render it proper to notice all the most important quarries that have yet been opened, and to give all the information which I am able to communicate respecting them.

To begin in the north part of the county, we find in North Adams a marble quarry of snowy whiteness; and as appears from the analysis that has been given, of great purity. It is indeed a pure highly crystalline carbonate of lime; free from magnesia, and almost free from iron. Large blocks of it are easily got out. At present, however, it is not so favorably situated in respect to an extensive market as the more southern parts of the county; and much of it is so highly crystalline as to mar its beauty; and probably also its strength: Yet it is a most valuable rock.

In New Ashford are several quarries of excellent marble, of a less highly crystaline character and a finer grain than that in Adams. The excavations have been made chiefly near the center of the town; and formerly a good deal of stone was sawed. But the business is not now carried on very extensively; not on account of any deficiency of materials, or defects in the stone, but because the quarries in the more southern parts of the county are nearer to good markets.

The western parts of Lanesborough furnish admirable facilities for the marble business. And the quarries there are very extensive. The stone is very much like that in New Ashford; being in fact a continuation of the same beds, which in Lanesborough are more fully developed and expanded. The analysis of three specimens of the best white and gray marble, as given in the general table, shows that they are very pure carbonates; scarcely exceeded by any others. A specimen of this marble may be seen in the Capitol at Albany; which is constructed of it. Greater facilities of transportation would undoubtedly much increase the demand for this marble.

In proceeding southerly, the next large quarry of marble is in the west part of Pittsfield, where inexhaustible quantities and of a good quality may be obtained.

To the south of Pittsfield the limestone formation is divided by a mountain range of mica slate. The westerly branch contains most of the stone best fitted for marble. West Stockbridge has long been celebrated for the great quantity and excellent quality which it produces: and from the table of analysis, it may be seen that the best varieties from that place vie in purity with any in the county. The small quantity of magnesia which they contain, does not probably affect their value at all: and the amount of iron, an ingredient which in my estimation is more likely than any other almost to injure marble, is scarcely worth mentioning. The marble of North Adams is perhaps a little nearer to absolute purity as a carbonate of lime, than that of West Stockbridge: but then the latter is more compact and firmer; qualities of high importance in good marbles: and often the translucency on the edge is as great as in good statuary marble. The quarries are numerous in this town, in almost every part of it. Most of the marble used in building the city Hall in New York, was from Fitch's quarry in the south part of the town. But at some of the other quarries, the stone appeared to me to be of rather a more delicate quality. A part of that in the State House in Boston is from the same town. It is fortunate that such immense quantities of so fine marble should occur at the intersection of two great rail roads: one of which, that to Hudson, is already opened to the west and will be soon easterly to Springfield and Boston: and in a few years to Albany.

The same range of limestone extends through Alford, Egremont, and Sheffield; and in several places in all these towns quarries are opened; and the quality is good. In the north part of Sheffield, is the quarry from which the marble is obtained for most of the columns of the Girard College in Philadelphia. This quarry is two miles north of the village. The strata, which are very thick, have an easterly dip of 60 or 70°. Blocks 50 feet long are sometimes blasted out by filling the crevices with gun powder; and masses of immense size are carried on carts constructed for the purpose, with large wheels, over the Taconic range, to the Hudson: where they are shipped for Philadelphia. Analysis shows this to be a quite pure carbonate; and yet I do not think it as delicate a stone as some other varieties in the county. The situation of the quarry however, is very favorable for exploration.

A mile or two west of the village of Great Barrington, is a quarry of the most beautiful clouded marble in the State: as may be seen by the specimens (Nos. 439.440.441.1932.) in the State collection. By analysis it appears that this rock contains nearly 40 per cent. of magnesia. This probably renders the stone more liable to break; still it is a substantial and certainly a beautiful marble, well adapted for mantle pieces and jambs. I find also that it is flexible: and since the flexible marble of New Ashford contains 16 per cent. of magnesia, I suspect this substance has

an agency in imparting this singular property; and I doubt not that numerous localities of flexible limestone may be found in Berkshire county.

In the year 1824 Professor Dewey estimated the value of the marble dug in Berkshire at $40.000. Charles B. Boynton, Esq. who has the principal direction of the marble business in West Stockbridge, has been obliging enough to ascertain the quantity dug in 1839: and he estimates it at $200.000. This rapid increase shows the high estimation in which the Berkshire marbles are held abroad. Until 1838 there existed no increased facilities for its transportation: and now a single rail road from the Hudson to the western limits of the county, is the only means of transportation not previously enjoyed. But soon this rail road will be completed to Boston, and the Housatonic rail road will connect the county with Long Island Sound. I regard therefore, an estimate of Mr. Boynton as very moderate, when he says; that "if general prosperity continues five years, Berkshire will at that time export marble to the value of half a million." He adds that "the demand for this article is constantly ahead of our means of supply: and this fact is now beginning to be understood abroad, and capital seeks investment among our hills and water powers." When we add to this statement, the great increase that will doubtless take place in the manufacture and export of quicklime, it will give some idea of the great value of the limestone deposits of Berkshire: of which its inhabitants generally seem to me to be little conscious.

O Fortunatos nimium sua si bona norint!

Mr. Boynton invented several years ago, and has long had in successful operation, an ingenious machine for planing marble. It would be gratifying, were this the proper place, and had I room, to give a description of this instrument. But no one can see it in operation without being satisfied that it must produce a very great saving of time and labor. It not only cuts all plane surfaces so smooth that for ordinary purposes they require no polishing, but also all strait mouldings and grooves with great facility and exactness.

I have a few suggestions to make respecting the means of determining the comparative durability of marbles from different localities: but as they will some of them apply to other rocks, I shall reserve them till I have completed the list of our rocks useful for architectural purposes.

## *Use of Limestone for Mortars.*

The most important use to which limestone is applied is undoubtedly in the preparation of various kinds of mortar. For while marble must be employed only by the most wealthy, there is scarcely an individual in the community that does not sometimes use lime mortar: and none could be comfortable without it. I hope, therefore, that any suggestions which I may make, whose object shall be to reduce the price or improve the quality of the quicklime generally burnt in Massachusetts, will be received with candor.

The burning of lime and its conversion into mortar, have within a few years received much attention: especially in France, by Vicat, John, and Berthier; who have arrived at some important practical results. And as these are not generally accessible in this country, I shall briefly state them, so far as the present state of knowledge in Massachusetts on the subject seems to demand.

### *Calcination or Burning of Lime.*

The burning of lime, so as to expel the carbonic acid, is the essential prerequisite in the formation of mortar: and it is accomplished in three modes: 1. Without a kiln: 2. By an intermittent kiln: and 3. By a kiln in constant operation; or as it is sometimes called, a *perpetual kiln.* The fuel employed is peat, coal, anthracite, or wood.

1. *Without a Kiln.* In Wales and Belgium the limestone is sometimes piled up in large conical heaps, the fragments being left much larger than when burnt in a kiln, and mixed with wood sufficient to burn it. The pile is then covered with turf exactly like a coal pit, and the process of burning is conducted exactly like that of a coal pit. In Belgium, a pile 16 feet diameter at the base, and 12 feet at the summit, occupies in burning six or seven days; and strange as it may seem, the lime thus produced is constantly preferred, at the same price, to that burnt in a kiln. I am not aware that limestone is ever burnt in this manner in this country: and yet I do not see but it might in some cases be a very desirable mode, especially where fuel is plenty and time and means are not at hand for building a kiln.

2. *Intermittent Kiln.* This is the most usual mode of burning limestone in this country. The kiln consists usually of a square or circular chimney, sometimes large and high enough to hold 900 bushels, but usually smaller, constructed at least on the inside, of stones that will bear a strong heat. In this chimney the limestone is piled up so as to leave an arched cavity underneath, as a place for the fire; which is usually continued several days before the calcination is completed. The fire is then allowed to go down, and the whole contents of the kiln are withdrawn to make room for a new charge.

It is obvious that by this mode of burning limestone, there is an immense loss of heat, as well as of time, in consequence of allowing the kiln to cool between each charge. Some saving of fuel may be made by constructing the kiln in the form of a cask, or egg, with the extremities cut off. A far more effectual remedy is to substitute the perpetual kiln, which will now be described. Where it is wished, however, to burn only a few hundred bushels of lime in a year, the common kiln may be cheapest.

3. *Perpetual Kiln.* This kiln is so constructed that the portion of lime which has become thoroughly burnt, can be removed without discontinuing the fire. And thus by removing the burnt lime from the bottom, and filling in at the top with fresh limestone, the process may be continued until the furnace needs repairs; which, in Belgium, is attended to once a year.

Fig. 1. exhibits the elevation, fig. 2. a vertical section, and fig. 3. a ground plan, of one of the most approved perpetual kilns, as it is constructed in Prussia; in which one part of wood and four parts of peat are employed. *d, d, d, d, d,* are five openings at the bottom, for withdrawing the lime as it is burnt: *c, c, c, c, c*; fire furnaces for the fuel, whose mode of connection with the cavity where the limestone is placed, may be seen at *c*, in the vertical section: which also shows at *d*, the manner in which the lime may be withdrawn. At *a, a,* is shown a lining of fire brick; back of which, is a cavity, *b, b,* filled with cinders, which act as a non-conductor of heat. The outside is built of rough stone. Its size can be learnt from the scale of English feet attached to fig. 2. It produces about 250 bushels of lime daily. ***See Dumas' Chimie applique aux Arts, &c. Tome Deuxieme, p.*** 489.

Fig. 1.

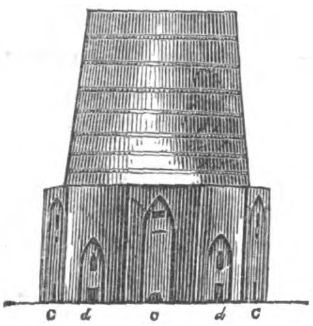



Fig. 2.

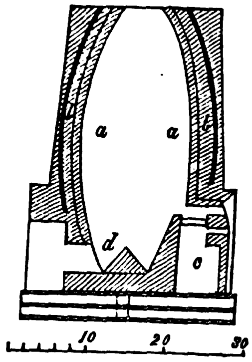



Fig. 3.

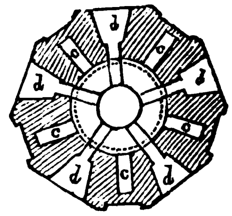



Fig. 4. is a vertical section of a plain perpetual kiln, which I visited in the north part of Richmond, Berkshire county. It is 25 feet high, and built of alternate layers of fire brick and stone. It is four sided; consisting of a single strait chimney, 4 feet square on the inside, and 8 feet on the outside; making the walls 2 feet thick. To the height of 7 feet from the bottom, it is 12 feet in one direction, for the purpose of making room for the furnaces, *d, d,* in which wood only is burnt, and which are 2 feet high, and 20 inches wide. For the passage of the heat into the limestone in the chimney, the bricks are laid up like a grate, as shown in Fig. 5. But it is obvious that an iron grate must be much better; and probably in the end more economical. *a, a,* are ash pits beneath the fires: *b* an opening for drawing out the lime from the bottom of the chimney, which is built towards its bottom exactly like the hopper to a grist mill; the opening at the bottom being about 18 inches square. This kiln consumes from 2 to 2 1-2 cords of wood daily, and produces 75 bushels of lime, which is drawn out at intervals of 8 hours. I do not suppose that this kiln is built in the very best manner: yet having been in successful operation for seven years, and being an easy one to construct, I thought a section of it might be desirable. The great quantity of wood consumed in proportion to the daily produce of this kiln, shows that there must be some defect in its construction. The proprietor, however, was about to rebuild it when I visited it in the autumn of 1838. All the parts may be measured by the scale of feet attached to Fig. 4.

Fig. 4.

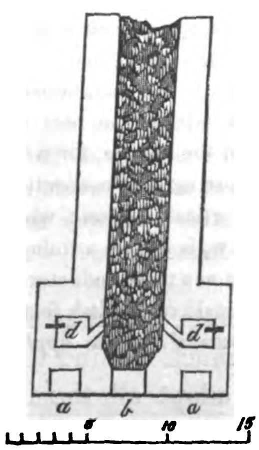
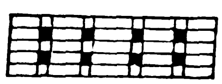



Fig. 5.



Besides the perpetual kiln that has been described in Richmond, another on the same plan exists in Lenox ; and these, so far as I could learn, are the only kilns of this kind that exist in the whole of Berkshire county. Nearly all the lime prepared there, is burnt in the old fashioned intermittent kilns. Indeed, I found among some of the lime burners there, a prejudice against the perpetual kilns ; as if they did not accomplish the work thoroughly. These facts have surprised me, when I consider what a great and increasing demand there must be upon Berkshire for lime from other parts of New England ; and being confident that it will be quite an easy matter to reduce the present cost of burning lime there, at least one half: and probably a great deal more. Mr. Haddsel of New Marlborough, who has burnt a vast quantity of lime stone for the last 30 or 40 years, (at present he burns about 12000 bushels annually,) and whose lime is considered very good in the Hartford market, told me that the cost of burning and preparing it for market would not fall much short of 25 cents per bushel. His kiln holds 700 bushels, and he consumes 40 cords of wood at a charge. Estimating the wood at $1.50 per cord, and this is probably too low, the cost per bushel is 8 1-2 cents. Dr. Jackson, in his second Report on the Geology of Maine, states the cost of fuel per bushel at Thomaston, where the old kilns are used is 8 cents. Now Professor Mather, in his second Report on the Geology of the First District of New York, states that lime is burnt in the perpetual kilns at Barnegat on the Hudson, where 720,000 bushels are annually prepared, for less than 2 cents per bushel :—the fuel costing less than one cent ; and the labor of tending the kiln about the same ; while the expence of raising the stone is trifling. In Connecticut, according to Professor Shepard, in his Geological Report, an intermittent kiln in Reading, that holds 1200 bushels, requires for a charge 40 cords of wood ; another in Brookfield, that holds 700 bushels, requires 35 cords ; and another in Derby, that holds 270 bushels, requires from 8 to 10 cords. If the wood be put at $2.00 per cord, the average price per bushel for these three kilns would be about 8 cents. But according to the same report, the perpetual kilns of Pennsylvania burn 700 bushels of lime with 8 cords of wood ; and one and a half tons of anthracite: which, (putting the wood at $2.00 per cord, and the anthracite at $6.00 per ton,) amounts to 3 1-2 cents per bushel. In New York, Mr. Shepard says, they burn 2000 bushels of lime with 12 cords of wood: which, at the same price, is only a little over 2 cents per bushel. The proprietors of the perpetual kiln in Whately, that has been already described, estimate that their fuel, which is entirely wood, costs them from 3 to 4 cents per bushel ; as stated in Mr. Nash's letter inserted on a former page.

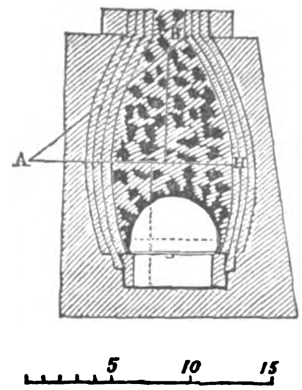
It ought to be mentioned that the fuel used at Barnegat is anthracite ; which there costs $6.00 per ton : and this is undoubtedly more economical than wood. But the greater part of the difference in the cost of the fuel at that place and in Berkshire, results from the character of the kilns employed as the other facts above mentioned already prove. And if desirable to employ anthracite in Berkshire, it can probably be transported by rail road at so low a rate, as to render it practicable. It is said, also, that coal dust, which costs in New York $1.75 per ton, will answer well for burning lime. Does not this fact deserve the attention of the proprietors of those lime quarries in the eastern part of Massachusetts, that have been abandoned on account of the high price of fuel. Dr. C. T. Jackson, in his second Report on the Geology of Maine, states that it has been estimated, that even at Thomaston in Maine, the use of coal would reduce the price of lime from 8 cents per bushel, to 5, and perhaps 3 cents. And if so, why may not the preparation of lime be extensively resumed in the eastern part of Massachusetts?

From these facts I cannot but infer that Massachusetts, proud as she justly is of her skill in manufactures, is in this art very much behind the times. And I have no doubt that were those concerned to adopt all the improvements that have been introduced into the preparation of quicklime, in one

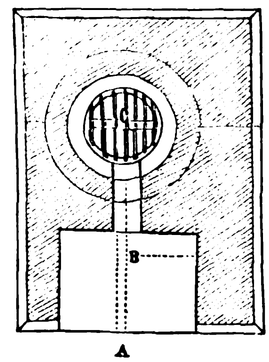
year the price of that article might be reduced one third, if not one half, *while the manufacturers would realize a greater profit than they now do.* This is particularly true of Berkshire county, which possesses an inexhaustible amount of this valuable material: but her citizens generally, it seems to me, are but little sensible of the treasure in their hands. Were only the fragments of pure limestone, that now lie useless around the marble quarries in West Stockbridge, Lanesborough, New Ashford, Adams, Sheffield, &c. to be burnt into lime, it would furnish a supply for the whole state for a great number of years. I am not aware that such a use is made of these fragments in a single instance; although the whole expence of quarrying is here saved. Is it said that there is little or no demand for the lime when prepared? But why not act on the commercial principle, that by increasing the supply, a demand can be created. Surely there is need enough for ten times more lime than is now burnt in Berkshire, in the region lying east of the county. And since rail roads will soon be in operation that can transport it thither, it becomes the interest of the inhabitants of that county to introduce all the modern improvements possible into its manufacture. Lime is sold at Barnegat for 6 cents per bushel: why can it not be prepared nearly as cheap in Berkshire? I confidently expect that the day is not distant when it will be: and then it will be in the power of our farmers, a good deal beyond the limestone district, to use it upon their land. At present the burning of lime is a business, so far as I could learn, not very profitable to those engaged in it in Berkshire county. But when its price shall be reduced one half, and ten times more is burnt, I predict that it will become profitable. I have been surprised to find how little limestone is burnt in that part of the state. It is a singular fact, that in most of those towns that have been most distinguished for the burning of lime, such as Washington, Hinsdale, and Peru, *no ledges of limestone occur*: but dependence has been placed entirely on the loose blocks that diluvial action has driven thither from the neighboring towns. And I have been assured that the inhabitants of some towns, which are based upon good limestone, transport most of the lime that they use from quarries in towns where very little exists in ledges, under an idea that they have no limestone where they live that is worth burning!

The use of peat in the burning of lime deserves the attention of those who own beds of the stone in the eastern part of Massachusetts. For the best European writers declare that it is decidedly more economical, and better in other respects, than wood. Figs. 6 and 7 are a vertical and horizontal section, the latter taken at the height of the grate,—of a kiln adapted for the use of peat.

Fig. 6.




Fig, 7.




A. Fig. 7, is an arch, and B, an embrasure, for introducing the peat and withdrawing the lime. The grate C, is composed of straight bars of iron resting upon a circular bar, which lies upon the brick work. The lining should be of fire bricks; though this is not indispensible. The sides of the kiln are curved; the radius of curvature being represented by the lines A H, A B, Fig. 6: whose length can be determined by the scale of feet at the bottom: and indeed, the same is true of every other part of the kiln; so that more particular description is unnecessary. Its height above the grate is about 18 feet, and its greatest width about 8 feet. In this kiln according to Dumas, (*Traite de Chemie applique aux Arts, Tome Deuxieme, p.* 488.) one cubic foot of limestone requires only two cubic feet of peat to burn it. Hence, next to anthracite, this appears to be the cheapest kind of fuel.

"When this furnace has been constructed," says Dumas "it should be left several days to dry slowly: when the fire is lighted, it should be done little by little, and gradually increased, lest the sudden contraction of the mortar should cause large fissures. The stone should be piled up in the kiln in the form of a hemisphere, so as to leave spaces of 2 or 3 inches between the fragments: the largest of these being collected near the center of the kiln, &c "—"When it is thus filled with stone, a muffled (*etouffe*) fire should be kept up on the grate for 10 or 12 hours. The smoke will blacken the stone very much to the top of the furnace. This operation, which is called the *smoking*, is intended to heat the whole mass by little and little. If heated too rapidly, the compact fragments would shiver in pieces by the rapid expansion of the water, and tend to choke the kiln."

## *Varieties of Limestone.*

On the continent of Europe three kinds of quicklime are distinguished by the different sorts of mortar which they produce. 1. Fat lime: (*chaux*

*grasse)* 2. Meagre lime: 3. Hydraulic lime. The fat lime contains at least 90 per cent. of pure lime: But when the magnesia, silica, alumina, iron, and manganese, which it contains, amount to 20 per cent. it becomes meagre: that is, these foreign matters affect very much the mortar that is made from the mixture. When these foreign substances, however, are in considerably large proportion, the lime sometimes becomes hydraulic; that is, it will harden under water.

### *Fat Lime.*

This being derived from an almost pure carbonate of lime, slacks with great energy and the evolution of heat; forms a fine paste with water; admits the addition of a great deal of sand; is more easily laid on by the mason; and therefore, is the most economical for common purposes. On all these accounts it is regarded as the best kind of lime; and sought after the most. For it is not generally known in this country, that it does not form so hard and durable a mortar as the next variety.

### *Meagre Lime.*

Although this kind of lime often slacks slowly and less perfectly than fat lime, and when water is added, forms a less perfect paste, and therefore, does not work so well with the trowel; and as it takes up less water and bears less sand, is therefore more expensive, yet after all, it hardens with greater certainty, and to a greater degree, and forms a more enduring and stronger cement. It is especially valuable for the property which much of it possesses, of hardening in damp as well as in dry places; and where mortar is exposed to the weather, it is by far the best. Nevertheless many of the circumstances mentioned above, produce a prejudice against this sort of lime, especially among brick layers.

It will be seen from the table of analyses of the Massachusetts limestones, that this variety of lime is very abundant among us, especially if we include under it, as is done by European writers, that which contains a large proportion of magnesia. I have had no opportnnity of trying but one variety of the meagre lime, and that is the kind that has lately begun to be burned in Whately. Having occasion to plaster a building upon the outside it seemed to me that this lime would be well adapted for the purpose. I tried it by mixing one part of unslaked lime with one part of sifted ashes, and one part of sand, and found it to produce a cement that spread well and became very hard, and at a few rods distance can hardly be distinguished from granite or sandstone. The outer coat, however, not having been put on in proper season after the first, does not adhere well. And although the Whately lime answers for outside work better than anyI have seen, yet I doubt whether in our climate, it be the best economy to cover the outside of buildings with any kind of calcareous cement. But if it be done, meagre lime is the best; and I doubt not that several other varieties in the State will answer as well as that from Whately. I presume however, that when there is not more than 50 per cent. of carbonate of lime in a rock, it will not produce cement of much value.

It will probably surprise the inhabitants of Berkshire county, as it did me, to find that by far the largest part of the limestone burnt there, contains not less than 40 per cent. of the carbonate of magnesia. The fine looking stone burnt in the south part of New Marlborough and Tyringham, near the center of Lee, and in the east part of Lanesborough, from which places great quanti-

ties of lime are carried out of the county, and it is in high repute, is all genuine magnesian limestone. The same is true of the quarries in the eastern part of the state, at Bolton, Chelmsford, Littleton, &c. Now it is certain that magnesia does not form a paste with water; and yet, so far as I can ascertain, this kind of lime is preferred to that which is pure; because it becomes harder and is usually whiter. But I consider that there is yet too much doubt resting upon the use of magnesian lime in agriculture to render it expedient to employ it upon land when other lime can be procured. And from the analyses of our limestones that have been given, our citizens can now judge where the different sorts may be obtained. In respect to magnesian limestone, however, there is another important use to which it has not been applied in this state which I shall suggest in treating of the next variety.

### *Hydraulic Lime.*

It has long been an important enquiry what ingredients are necessary in limestone to render it hydraulic; that is, to cause it to harden under water. Until recently but little success attended this enquiry: because the manner in which mortar is consolidated, was misunderstood. It was supposed to result from the absorption of carbonic acid from the atmosphere, whereby the lime was reconverted into a carbonate: so that the more completely this process was effected, the harder would the cement become. And this was thought to explain the reason why the ancient Roman cements, that are found in old ruins, are so hard. But upon analysis it was found that these mortars rarely contained much carbonic acid; and that in general they were harder, the less of this substance entered into their composition. (*Traite de Mineralogie, par Beudant, Tome Premier, p.* 690.) That mortars do, however, absorb carbonic acid on their surface, and that this is one of the causes of their induration, can hardly be doubted. But it is not the principal cause. Silica operates as an acid in mortars, and forms silicates of lime, magnesia, alumina, &c. and this probably is the principal cause of their consolidation. In this state silica exists in rocks, and to this fact chiefly they owe their hardness: and could the materials of mortar be mixed in such proportions as they exist in rocks, and under as favorable circumstances for induration, they would become as hard as the rocks; as in fact they do sometimes.

This theory shows us the use and even necessity of sand mixed with lime, to form good mortars. It shows us also, why it is better to have this siliceous matter exist naturally in the rock than to introduce it artificially, because nature mixes it more perfectly than art can do. But why should some mortars become silicates only in the air, and others with more facility under water? It is the opinion of distinguished chemists that the latter class are converted, when under water, into hydrated silicates; while the former, not undergoing this process, are more or less dissolved when immersed, and become mere anhydrous silicates in the air. But the analyses that have been made of these dif-

ferent varieties of limestome do not afford a satisfactory reason why some of them are hydraulic and some are not. Yet it is hence ascertained that certain ingredients besides the lime, are necessary to make them harden under water. It was formerly thought that this property depended upon the oxide of iron, or manganese, which they contained. But the numerous accurate experiment that have been made on the subject, prove that silica is the most important ingredient on which the hydraulic character depends. The results of all these experiments however, I give in the words of Dumas. "It follows," says he, "from all these facts, that silica alone is able to form with lime a combination eminently hydraulic: while magnesia alone, or a mixture of the oxides of iron and manganese, cannot produce a similar combination, but renders the lime meagre, without communicating to it the property of hardening under water. Synthetic experiments confirm the results of analysis; and prove farther. 1. That alumina alone has no more efficacy than magnesia in rendering lime hydraulic: 2. That silica is an ingredient essential to these varieties of lime: 3. That the oxides of iron and manganese, far from playing a part so important as some attribute to them, are on the contrary very often altogether passive: 4. That the best hydraulic lime results from a mixture of silica, lime, and magnesia, or alumina."—"We must, therefore, consider hydraulic lime as a silicate of lime, or a silicate of alumina and lime, or finally as a silicate of magnesia and lime, with an excess of base. These compounds placed in water produce hydrates; or other combinations of the hydrated silicate with the hydrate of the base in excess." (*Chimie appliqué aux Arts, Tome Deuxieme, p.* 512.) More recently another distinguished chemist, Professor Mitscherlich of Berlin, says in respect to magnesian limestone for hydraulic cement, that "according to experiments in the small way, magnesian limestone merits the preference over the carbonate of lime." (*Elemens de Chemie par E. Mitscherlich, Tome Troisieme, p.* 120. *Bruxelles,* 1836.) Vicat also, recently inclines to the same opinion; and in our country, Professor William B. Rogers, the able state geologist of Virginia, has made numerous analyses of the hydraulic limestones of this country, from which he not only infers that magnesia operates favorably upon the hydraulic character, but even suggests that this property may depend upon the magnesia, rather than upon the silica. He finds that in all the hydraulic limestones which he has analysed, the carbonate of magnesia bears to the carbonate of lime the proportion of three to five: and he supposes that by this circumstance we may probably determine whether any limestone is hydraulic. Without doubting at all the accuracy of Professor Rogers' analyses and experiments, I confess that I do not know how to reconcile the principle, that the hydraulic character always depends upon magnesia, with the numerous analyses and experiments that have been made in Europe on the subject. In the

table below I shall give some of the analyses by Berthier of the best hydraulic limestones in France; most of which contain but a very small proportion of magnesia: and those which are artificial, and which are in high repute, contain none. Even the septaria of England, from which the famous Roman or Parker's cement, the best hydraulic cement in the world, is obtained, contains only one 200th, part of carbonate of magnesia; and a similar rock in France and Russia contains none. On the other hand, in some of the specimens analyzed by Prof. Rogers, the silica is less than two per cent.; and yet they form good hydraulic cement. We have then good mortar of this description, sometimes almost without silica, but containing magnesia; and sometimes without magnesia, but containing silica. Must we not hence infer, that the hydraulic character does not depend entirely upon either of these substances: but rather upon the mode or other circumstances of their combination with the lime: in other words, that they may replace each other.

I have annexed to the following table of analyses, the composition of some of those artificial hydraulic cements, which it is well known are frequently prepared in Europe, and with great success. I have also added the analyses of those limestones in Massachusetts, that so much resemble those from which hydraulic cement is prepared in other parts of the world, as to deserve a trial whether they will not also harden under water. It will be seen that the analyses of Prof. Rogers give the composition of 30 parts of the rock: while the others assume 100 parts as the standard. Berthier's analyses are given in the second volume of Dumas' *Chimie Applique aux Arts:* while those of Prof. Rogers are derived from his Report on the Geological Survey of Virginia for 1838.

*Limestone moderately Hydraulic.*

| LOCALITIES. | Carbonate of Lime. | Carbonate of Magnesia. | Carbonate or Oxide of Iron. | Carbonate of Manganese. | (Argile) Clay. | Silica. | Alumina. | Alumina and Oxide of Iron. | Carbon. | Water. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| France (Loire) | 90.0 | 5.0 | | | 5.0 | | | | | | |
| do (Ain) | 85.8 | 0.4 | 6.2 | | 5.4 | | | | | | |
| *Eminently Hydraulic.* | | | | | | | | | | | |
| France (Gard.) | 82.5 | 4.1 | | | 13.4 | | | | | | |
| do | 79.2 | 2.5 | 6.0 | | 3.8 | 6.5 | | | 2.0 | | |
| do Senonches very famous. | 80.0 | 1.5 | | | 1.0 | 17.0 | | | | 1.0 | |
| Virginia near Shepherds town. | 15.94 | 6.49 | | | | 6.50 | | 0.64 | | 0.12 | 0.31 |
| do - do | 16.76 | 11.76 | | | | 0.77 | | 0.35 | | 0.13 | 0.20 |
| do Jefferson county, | 8.48 | 6.56 | | | | 13.20 | | 1.20 | | 0.40 | 0.16 |
| New York, Much used— | 14.46 | 10.73 | | | | 3.63 | | 0.36 | | 0.82 | |
| Kentucky, Louisville, | 16.51 | 7.25 | | | | 4.54 | | 0.79 | | 0.37 | 0.54 |

*Massachusetts Limestones perhaps Hydraulic.*

| No. | LOCALITIES. | Carbonate of Lime. | Carbonate of Magnesia. | Carbonate or Oxide of Iron. | Carbonate of Manganese. | (Argile) Clay. | Silica. | Alumina. | Alumina and Oxide of Iron. | Carbon. | Water. | Loss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 494. | Walpole, | 70.30 | | | | 29.70 | | | | | | |
| 1942. | Becket, | 58.31 | 28.61 | 1.24 | | 11.84 | | | | | | |
| 448. | Williamstown, | 52.31 | 32.79 | 0.74 | | 14.16 | | | | | | |
| 496. | Stoneham, | 59.28 | 15.71 | 1.21 | | 23.80 | | | | | | |
| 211. | W. Springfield, Paine's Quary. | 93.48 | 0.90 | | | 5.60 | | | | | | |
| 1737. | Springfield Chicopee, | 86.80 | | | | 13.20 | | | | | | |
| 1941. | Middlefield, Cole's Brook, | 56.25 | 31.56 | 1.12 | | 11.07 | | | | | | |
| 1944. | Sherbune, | 60.43 | 29.84 | 2.36 | | 7.37 | | | | | | |
| 1918. | Concord, | 77.33 | 1.19 | 1.65 | | 19.83 | | | | | | |
| 1946. | West Natick white crystalline, | 72.10 | 7.50 | | | 20.40 | | | | | | |
| 1950. | do yellow, | 61.18 | 12.30 | 1.27 | | 25.25 | | | | | | |

Except the specimens from Springfield and West Springfield, which have been tried, I infer the hydraulic character of the Massachusetts limestones above given, from their composition alone. I am strongly suspicious that the fact that they are mostly of the primary class, and crystalline, will operate unfavorably. The great importance of finding such limestones in different parts of the state, will, I trust, lead to a fair trial of those that I have pointed out. This may be done at first on a small scale, without much trouble; and I should myself have tried them all, had my attention been specially called to this subject in season to obtain large enough specimens from the different localities. It would be particularly desirable to find such limestone in the county of Berkshire: And even should none of those prove hydraulic, which I have analyzed from that part of the State, it ought not to discourage search after those, which will prove so: for hydraulic limestones are usually of a poorer kind, such as in Berkshire would be passed unnoticed, as of no value. I have little doubt but those may be found there, which will set under water. At any rate, probably some varieties of the marl, that have been recently found in Berkshire, will make hydraulic cement, if burnt in a proper manner. For says Professor Mitscherlich, "a marl which contains from 13 to 19 per cent. of clay, makes a good hydraulic mortar; and if the clay contains an excess of silica, this circumstance increases the good qualities of the mortar." (*Elemens de Chemie, Tome Troiseme.*) Now by referring to the composition of the Berkshire marls, as given on a former page, it will be seen that marls of the description here mentioned occur there; and probably at almost any of the localities a part of the beds may be found containing the requisite proportion of clay, that is, of silica, alumina, oxide of iron, &c.

The only limestone in Massachusetts that has hitherto been employed for hydraulic mortar, is that at Paine's quarries in the west part of West Springfield: where large quantities have been manufactured within a few years past; and I understand it to form a good cement; although I

infer from analysis, that it is rather too pure a carbonate of lime. But not improbably the specimen analyzed was above the average in this respect. The specimen given in the general table of analysis from Chicopee, in Springfield, contains more clay and would probably make a good hydraulic cement. It occurs in the bed of the Chicopee river, just below the bridge at the Chicopee Factory village, where I presume is a large quantity. It has never been burnt at all for mortar; and indeed its existence there is hardly known; although large quantities of it, with the associated sandstone, have been got out for building factories on the bank.

The limestone at this place, as also at Paine's quarries in West Springfield, is mostly fetid, sometimes perhaps bituminous. But there is another variety occuring on the Chicopee, as well as the Agawam, which I suppose will produce an hydraulic cement far superior to any that has yet been made in this New England. But this I shall describe farther on.

## *Artificial Hydraulic Mortar.*

When lime is not in itself hydraulic, it may be made so by mixing with it, either wet or dry, certain argillaceous matters, which have been burnt with the access of atmospheric air. Some of the clays used for this purpose in Europe resemble in composition the white clay from Martha's Vineyard, that is destitute of iron. Probably, however, the presence of iron will do no injury, and most likely many of our clays will answer. As to the kind of lime to be used, after what has been said there can be but little doubt but the magnesian would be much preferable. The proportion of the ingredients, and the precautions requisite to success, cannot be here given for want of room: but will be found in the works of Vicat, Dumas, and others. In this way, if in no other, can Berkshire and the eastern part of the state supply themselves with this mortar.

In Europe, however, ever since the days of Roman glory, it has been very common to employ, instead of clay, a kind of volcanic ashes called *Puzzolana;* which resembles burnt clay. In Holland great use has been made of a similar substance called *Tarras*, or *Trass*, which is decomposing basalt. The vescicular decomposing trap rock, not uncommon on the greenstone ranges in the valley of Connecticut river, appears to me so much like tarras, and puzzolana, that it would make a good substitute. I have accordingly subjected to analysis a specimen, from Mount Holyoke (No. 160.) in the north west part of Belchertown, where great quantities of it may be obtained in a state more or less approaching to powder. I have noticed the same substance along the eastern side of that greenstone range which extends through the eastern part of Deerfield and Greenfield. The following are the results of the analysis.

| | |
|---|---|
| Water, | 8.50 |
| Silica, | 53.70 |
| Alumina, | 13.00 |
| Peroxide of Iron, | 21.00 |
| Oxide of Manganese, | 0.19 |
| Lime, | 0.70 |
| Magnesia, | 0.15 |
| Sulphur, (from pyrites) and Loss, | 2.76 |
| | 100. |

By Bergman's analysis, Puzzolana has the following composition:

| | |
|---|---|
| Silica, | 55 to 60 per cent. |
| Alumina, | 19 to 20 " |

| | |
|---|---|
| Calcareous Matter, | 5 to 6 per cent. |
| Iron, | 15 to 20 " |

The correspondence between this analysis and that which I have given, is near enough to show that in all probability both substances would answer almost equally well for hydraulic cement. If our clays, therefore, will not answer for this cement, here is a substance that can doubtless be employed.

## *Roman Cement.*

In the year 1796, Messrs. Parker and Wyatts obtained a royal patent in England, for the manufacture of a peculiar kind of cement, which they denominated *aquatic cement*, and which subsequently obtained the name of *Roman Cement*. They were eminently successful, and others followed their example with the like success. It has become indeed, an important branch of business: and vast quantities are exported to foreign countries, where it bears a high price. It possesses the valuable property, after having been mixed with water, of hardening very rapidly, even in a quarter of an hour; whether in air or under water. Hence it is the most valuable sort of cement that is prepared from lime. In London, it is employed as a substitute for plaster of Paris, in preparing models: also for filling up crevices in walls, luting the joinings of aqueducts, restoring broken cornices, and other architectural ornaments, and for many other uses. Stones united with it become in a few hours as difficult to break through the joining, as in any other direction.

The material from which this valuable substance is obtained is a peculiar kind of concretionary limestone, occurring in nodules, of different sizes, which are usually traversed by veins of sparry carbonate of lime. These nodules, on account of being thus traversed, are called *Septaria.*

Now the valley of the Connecticut contains several localities of Septaria which are exceedingly like those of England. I have found them in quantity only in Springfield, on the Chicopee river; in West Springfield, on the Agawam, and at Wethersfield in Connecticut at a place called the Cove. The rock in the bottom of the river at Chicopee Factory village, may be seen spotted with them; and at the quarry a few rods east of Cabotville, on the south bank of the same river, great quantities of them may be seen, that have been thrown away. At this place I noticed some as large as a man's head; but generally they are much smaller. On the Agawam river, a little above Midneag Factories, the quantity of this peculiar argillo-ferruginous limestone appears to be greater than in Springfield: for here it forms layers between the strata of shale, of one, two, or three inches in thickness: which appears like clay that has been exposed to the sun, till it has cracked in all directions by desiccation. Upon the whole, I have a strong hope that

there will be no deficiency in the quantity of the material, should it be found to form the Roman cement, so as to make it an object to manufacture it.

On the Continent of Europe this sort of limestone has been sought after with great eagerness. I am not aware that it has been found except at two places in France, and one in Russia. I shall put down an analysis of a specimen from England and another from France, in order to compare these with the specimens which I have described in Springfield, whose composition is subjoined.

| COMPOSITION. | English Septaria. (By Berthier.) | French Septaria. (By Berthier.) | Chicopee Factories. No. 1764. | Cabotville. No. 1763. | Agawam Manganesian No. 216. | Do. 2d Specimen. No. 1758. | Do. Argillaceous. No. 1759. |
|---|---|---|---|---|---|---|---|
| Carbonate of Lime. | 65.7 | 61.6 | 46.06 | 43.69. | 30.81 | 26.04 | 55.16 |
| Carbonate of Magnesia. | 0.5 | | 27.35 | 39.35 | 18.33 | 13.45 | 22.21 |
| Carbonate of Iron. | 6.0 | 6.0 | | | | | |
| Carbonate of Manganese. | 1.6 | | | | | | |
| Silica. | 18.0 | 15.0 | 20.97 | 13.57 | 45.33 | 54.00 | 15.56 |
| Alumina. | 6.6 | 4.8 | | | | | |
| Oxide of Iron. | | 3.0 | 5.62 | 3.39 | 5.53 | 6.51 | 7.07 |
| Water. | 1.2 | 6.6 | | | | | |

Two of the above specimens from West Springfield, that are denominated *manganesian*, probably contain too much silica to make good Roman cement, or even the common variety of hydraulic cement; though they will harden considerably under water. As to the septaria from Chicopee and Cabotville, and the argillaceous limestone from Midneag, their composition corresponds essentially with that of the European Septaria, except that our rocks contain the most magnesia. But from the well known influence of this substance in causing lime to harden under water, the presumption is that its presence will rather assist than injure the hydraulic character. The earthy materials, made up of silica and alumina chiefly, exist in very favorable proportions. Suspecting the existence of manganese in most of the varieties, I subjected the second variety in the table (No. 1764.) to analysis, by fusion with soda, and obtained the following results.

| | |
|---|---|
| Carbonate of Lime, | 26.04 |
| Carbonate of Magnesia, | 13.45 |
| Silica, | 33.74 |
| Alumina and iron, | 15.13 |
| Manganese, | 11.64 |
| | 100.00 |

It is not probable that all the varieties of limestones from the Springfields, which I suppose would produce hydraulic, if not Roman cement, contain as much manganese as that whose analysis is given above. But they all probably contain some: and it is well known that manganese is highly favorable to the hydraulic character: so much so that some writers have contended that it is the chief thing on which that character depends.

In order to bring the preceeding suggestions to the test of experiment, I burnt some small pieces of the Septaria from Cabotville, and two varieties of limestone from West Springfield, in a chemical furnace, and having pulverized them, I added water, till they were converted into a paste. Two of the specimens, viz. the septaria from Cabotville, and the argillaceous limestone from West Springfield, hardened about as quick as calcined plaster of Paris, say in 15 minutes. In half an hour, they had become harder, and the process of induration continued for several days, until they became very hard. I tried them both in air and under water; and although I think the process was more rapid in air than water, yet the difference was not great. Upon the whole, I think the stone from West Springfield hardened rather more rapidly than the Septaria, and became more solid. How extensively this rock occurs on the Agawam, I do not recollect. I only remember that several analagous varieties of limestone occur west of Midneag Falls, frequently several inches thick. I feel a strong confidence, therefore, that I can point out there (if the recent dam at Midneag has not concealed the spot by water,) enough of this stone to justify efforts to convert it into Roman cement.

The other variety from West Springfield which I burnt and converted into mortar, was that described above as having 54 per cent. of argil or clay and a considerable quantity of manganese. This hardens much slower in the air than the other, and is but little hydraulic: as we might expect from the great quantity of earthy matter which it contains. But being obviously of the same general character, as the others, the addition of quicklime would probably make it a good hydraulic lime, if not Roman cement.

There can be no doubt that the Septaria from Chicopee Factory village will answer as well as that from Cabotville for the Roman cement: for its composition is almost precisely the same, and the two localities are separated only a short distance. Now then we have three localities of this very valuable substance, which so far as I can learn, has been prepared rarely in the United States, although common hydraulic limestone is calcined in a great many places. But that which produces Roman cement is far more valuable. I cannot but hope that it may be found in large quantities within the bounds of the two Springfields: yet even if only a small quantity exists it will certainly deserve attention.

It ought perhaps to be mentioned that the English septaria, from which the Roman cement is prepared, is obtained from the London clay; a rock much more recent than the sandstone of this valley. But if the nature of the septaria be the same, and my experiments and analysis render this almost certain, it can make no essential difference from what part of the geological series it is obtained.

With these facts before them, I will not believe that the intelligent and enterprising inhabitants of the two Springfields will suffer this substance to lie much longer unnoticed. The interest which is taken in the discovery of a similar substance in France, may be learnt by the following remarks of Dumas, than whom scarcely a higher authority can be named. "This important discovery," says he, "must have the most happy influence on our great works of hydraulic architecture. No doubt but a substance so simple in its composition, may be found in many parts of the country. It is a matter of the highest interest that researches of this sort should be pursued with zeal: for their object is an immense improvement in the art of construction." (*Chemie Applique aux Arts, Tome Troiseme. p.* 525.)

Can it be that a material which excites so deep an interest among intelligent practical men in Europe, should not here awaken attention enough even to give it a fair trial, while we are yearly importing large quantities of the very same cement from England, which this rock would produce; and that too at a great expense? Suppose it yields a cement inferior to the English: yet may we not infer almost certainly, that it will produce a hydraulic mortar superior to any that is now prepared in the state. May not the man therefore, who first successfully brings it into the market, hope to realize a valuable pecuniary profit? At any rate, it can be tried at a very little expense on a much larger scale than I have done. But let me caution any one who shall undertake it, against being too speedily discouraged, should the first efforts prove unsuccessful. Although this limestone is burnt in the same manner as the other sorts of limestone, yet the management of the fire requires peculiar attention; lest the stone begin to fuse, which will render it totally unfit for cement. On the other hand, a temperature too low, will produce a meagre lime, that is not hydraulic. The process also must be carried through when it is begun, without stopping: as a suspension of the heat for a time, when the carbonic acid is partly driven off, will prevent the expulsion of the rest by a subsequent application of heat. But difficulties of this sort can be overcome by perseverance:—a virtue which the inhabitants of New England know well how to exercise.

### 10. *Argillaceous Slate.*

A more common name for this rock, at least for the most useful variety of it, is *roof slate*; be-

cause it is used for forming the roofs of houses. I have been inclined sometimes to regard the ranges in Quincy, Watertown, Charlestown, and Cheslea, as a fine grained variety of graywacke; but this question may be more properly considered in the scientific part of my Report. At any rate, this rock, in the towns above mentioned, does not split into layers sufficiently thin for roofing. But it is valuable for gravestones, the covering of drains, flagging stones, &c.; and for these purposes it is extensively wrought in Quincy, Charlestown &c.

### *Novaculite.*

This is a variety of argillaceous slate which is known in the arts under the name of hone, oil stone, turkey stone, and whetstone. It exists in beds of argillaceous slate in Charlestown, Malden and Quincy. It is not however, of a very good quality; and I am not aware of its being used for hones, or even for whetstones: although it might answer the purpose, if better materials could not be found elsewhere. M. Godon, in his account of the geology of Boston and vicinity, says that a compact feldspar is found there perfectly analogous to the turkey stone. I have found a variety of this mineral in Newbury, which I apprehend, corresponds with that described by this writer, and a specimen may be seen in the collection; but no fair trial that I know of has been made to employ this stone as a hone. (No. 1206.)

### *Roof Slate in Woreester County.*

The range of slate exhibited on the Map in the towns of Boylston, Lancaster, Harvard, Shirley and Pepperell, is associated with the peculiar mica slate that contains the Worcester coal. It answers for roofing in some parts of the bed and has been quarried for this purpose in Lancaster. It has been wrought considerably in Harvard and Pepperell for gravestones; and is transported a considerable distance for this purpose. The stratum is narrower near the north line of the State; but I have found no time to ascertain how far it extends into New Hampshire.

### *Connecticut River Slate.*

Although a large part of Bernardston is represented as composed of this slate, yet its characters are not perfectly developed till we pass into Vermont. In Guilford, Brattleborough, Dummerston, and even 50 or 60 miles farther north, it produces an excellent material for roofs, writing slates, &c.: and extensive quarries are opened in it in those towns. The best slate used in Massachusetts probably comes from this range. In Bernardston it is quarried to some extent for gravestones.

### *Berkshire Slate.*

The mica and talcose slate of the western section of the State, pass gradually into roofslate, but in most instances the characters of the latter are not very perfectly exhibited, until we have entered New York. There, however, in Hoosic, and other towns, it is quarried extensively for roofing; and the western part of Massachusetts is always sure of a supply of this valuable material from that quarter if not within its own limits.

### 11. *Graywacke.*

For the most part, this rock furnishes a coarse stone only fitted for a common wall; but sometimes its stratification is so regular, and its grains are so fine, that it answers well for underpin-

ning, step-stones, &c. It is quarried I believe in Brighton, and some other towns in the vicinity of Boston. At Pawtucket, on the Rhode Island side of the river, is an extensive quarry of a fine grained and slaty variety, which I should judge would form a good flagging stone; and immense quantities have been taken away for this object and for other purposes. On Canonicut island in that state, is also a valuable quarry of this rock.

Graywacke is sometimes beautifully amygdaloidal; that is, it contains numerous rounded or almond shaped nodules of some other mineral. In these instances, however, the base of the rock is rather *Wacke*, than graywacke. This wacke (which resembles indurated clay,) often forms the cement of graywacke. In Brighton it is of a reddish color, while the imbedded nodules are sometimes white, and often consists of white feldspar with epidote, which is of a lively green color; and these substances are not only in rounded massess, but in veins of irregular shape. The rock is hard and admits an imperfect polish. It then resembles porphyry and is elegant. A fine example of this is in possession of Hon. H. A. S. Dearbon, forming a pedestal for the bust of his father. It is only slightly polished, but would generally be mistaken for porphyry.

A similar amygdaloid occurs in Brookline, Newton and Needham. A variety still more beautiful is found in Hingham. The color of the base is chocolate red; and the nodules are red, green and white. Large blocks can be got out.

I think upon the whole, however, that the finest amygdaloid occurs in Saugus, on the hill a few rods east of the meeting house. The base is a pleasant green, and the nodules white compact feldspar, generally spherical, and thickly interspersed. I have little doubt that large blocks can be obtained at this locality; but as the base is softer than the nodules, it can be only imperfectly polished.

## 12. *New Red Sandstone.*

This rock occurs in Massachusetts, only in the vicinity of Connecticut river; along which on both sides, ranges extend from Middletown, Ct. to Vermont. It affords large quantities of good stone for building and other purposes. Some of the numerous varieties of this rock are slaty; and either of a red, gray, or black color. These varieties furnish good flagging stones; and the side walks of all the principal places along the river, are chiefly covered by them. In the more common varieties, the strata are from six inches to two feet or more in thickness: and for the most part the color is red, though sometimes gray. From these thicker strata is obtained most of the rock of this formation used in architecture. The most delicate variety occurs in Longmeadow and Wilbraham. It consists simply of an almost blood red sand, cemented probably by iron. It is remarkably uniform in its color and composition; and forms a beautiful and most valuable building stone; though liable to be easily injured and sometimes disintegrating by exposure. The quantity of this rock is inexhaustable, and it occurs from three to five miles from Connecticut river: the intervening region being nearly level. A great number of quarries are now explored; but I have no means of determining how great is the demand for the stone. The celebrated Chatham quarries, on the bank of the Connecticut river, in Connecticut, are opened in the same kind of rock, although a coarser variety.

Another variety of the new red sandstone, quarried in many places in Massachusetts and Connecticut, is coarser than the Longmeadow stone; but being harder, it is more enduring, though less elegant. This variety is quarried extensively for the Farmington Canal, in the sandstone range south of Mount Tom in West Springfield; also in Westfield and Deerfield. A gray and rather coarse variety is used in some places, e. g. in Granby, Mass. This indeed, with the other varieties mentioned above, forms excellent underpinning, door and window caps, and foundations and door steps; and like the Berkshire marble, they are sometimes wrought into sinks and other similar articles. The ease with which the rocks of this formation are wrought, forms a great recommendation; and, were they as enduring as gneiss and granite, these latter rocks would soon be neglected.

On the north bank of Connecticut river in Gill, at a place called the Horse Race, is a quarry of gray micaceous sandstone, which forms excellent flagging stone. Slabs of very large size can there be obtained. In the southwest part of Montague, 100 rods from Connecticut river, a quarry in red sandstone has recently been opened, which appears to me to bid fair to become one of the most valuable in the state. Most of the rock is slaty, and some of it is divided by cross fissures into joints of such form and regularity, that excellent flagging stones and underpinning may be split out at once; and need neither smoothing nor hammering upon the edges. The stone forms a hill of some 30 or 40 feet elevation, and of great length. Being so near the river the means of transportation are at hand.

### *Suggestions as to the causes of decay in rocks used for construction; and the means of judging beforehand as to their durability.*

The question is often asked if the geologist can determine by examination or tests, whether a rock will be liable to disintegration upon exposure to air or water: And it is a very difficult question to answer satisfactorily. Most of the remarks which I shall make on the subject will be mere suggestions; which will require the test of experiment before they can be of much practical importance.

In opening a new quarry, if any of the rock has long been exposed to the weather, it can be seen what is the effect of atmospheric agents: and if disintegration has hardly begun, a favorable prognosis may be given as to the durability of the rock. But if the surface has been deeply acted upon, it is unfavorable. This is the surest mode where it can be adopted, of settling this question. Nor in the present state of chemical geology, do I believe it possible to determine with certainty the durability of a rock without an actual trial. Yet the chemical constitution of a rock will enable us sometimes to predict whether it will be liable to disintegration.

Of all the ingredients in rocks, probably iron in some form, most exposes it to decay. If this exist as a protoxide, or a sulphuret, exposure to the atmosphere will most probably convert it into a peroxide: and if the quantity be considerable, this will produce disintegration of the rock. Sometimes, however, this change only communicates the stain of iron rust to the surface of the stone, while its solidity and durability are hardly affected. An example of this sort may be seen in one of the churches in Quincy, built of the sienite of that place. When built, the stone was of a good color: but it has become so much stained with iron, as very much to mar its appearance: yet I believe there is no disintegration. But in many places in the west part of Essex County, as in Reading and Topsfield, I have noticed the sienite to be crumbled down, and from its ferruginous aspect, I presume this proceeds from some metamorphosis of the iron. I impute the disintegration of some of the red sandstone, used for construction in the vicinity of Connecticut

river, to the same cause. Yet as the iron in this rock appears to be peroxidized when quarried, probably the disintegration may proceed from the conversion of the peroxide into the hydrate; or of the hydrate into the peroxide.

In the limestones of Berkshire county, the iron exists in most cases probably in the state of a protocarbonate; and this substance is very liable to decomposition. Probably, therefore, those limestones that contain the least iron, will form the most enduring and valuable marble. Analysis lends probability to this suggestion. For the best marbles of Berkshire County are almost destitute of iron; as the following statement will show.

| | | | |
|---|---|---|---|
| Marble of North Adams, contains of iron | | | a trace |
| do | Lanesborough, | 1st specimen | do |
| | | 2d do | 0.22 per cent. |
| do | West Stockbridge, | Fitch's quarry, | 0.14 " |
| | | Boynton's do | 0.08 " |

The two first specimens probably may contain as much iron as the three last: for I did not attempt to estimate it.

I consider the presence of a large quantity of magnesia in limestone as unfavorable to durability. For it is a general principle in chemical combinations, that the greater the number of ingredients in a compound, the more feebly are they held together; and a magnesian carbonate is much more complex than a simple carbonate of lime. Observation and analysis sustain this view. For it appears that with the exception of the clouded marble of Great Barrington, (of whose durability I have not been informed,) no valuable marble in Berkshire contains much magnesia. Again, we find that nearly all the valuable marbles hitherto explored there, are found along the western part of the county; while the limestones of the eastern portion, that abound in magnesia, afford but few. Besides, among these magnesian limestones it is common to see their surface crumbled into powder; while nothing of the kind is witnessed among the pure carbonates. This disintegration is most striking in the town of Canaan, lying south of Sheffield.

It is well known that potassa exists in feldspar in large proportion: and that this mineral frequently decomposes, and is converted into porcelain clay. In this process the potassa dissolves and carries away a large proportion of the silica; leaving most of the alumina. Must we not impute many instances of the disintegration of granite, to the agency of the potassa; since the other ingredients are quite inert? The same may be said of sandstone composed of fragments of granite and gneiss. I confess, however, that I see no reason why one variety of granite should easily decompose, while another, with as much feldspar, should resist the atmospheric agency of thousands of years.

Wherever carbonic acid is evolved from great depths in the earth, where the temperature is high, and forces its way through the rocks, it cannot but dissolve more or less, some of their ingredients, and render them more liable to disintegrate. This cause of decay applies more particularly to countries in the vicinity of volcanos. Yet it is thought by some geologists that carbonic acid gas does percolate through the soil in many regions far removed from volcanic action. I have sometimes been led to resort to this agency, to explain the fact, that the only granite occurring in Berkshire county, in the western part of Clarksburg, should disintegrate so easily. I have not noticed in its feldspar a tendency to decomposition: and yet its bowlders, that are strewed for 20 miles over the hills and valleys in a southeast direction, are almost incessantly crumbling to pieces. That free carbonic acid has pervaded the rocks of Berkshire county, in early times, in a very remarkable degree, and that it has even undergone decomposition while in them, I shall endeavor to show in another part of my report: but whether the process is now going on to any extent, I have no facts to determine; yet there are some indications that an extensive fault exists along the western part of that county.

If the views which I have presented are founded in truth, then benefit might sometimes be derived from chemical analysis in judging of the probable durability of rocks for architectural purposes. This is particularly true of limestones. But I will not farther enlarge on a subject on which I am able to cast so little light.

## 13. *Clay for Bricks.*

The clay that has been already described as serviceable in agriculture, is employed almost every where for making bricks. There are but very few towns in the state, and those very mountainous, where this clay does not occur in a state more or less pure. I regard all of it as belonging to the diluvial formation; and it seems to have been deposited in every basin, where the retiring diluvial waters were kept quiet by the surrounding hills. Consequently we find it at very different levels; and having been derived from the rocks in the vicinity of its deposits, its color and composition will somewhat vary. In most instances its color is bluish, passing sometimes to greenish. But in the eastern parts of the state, as at Lowell, Kingston, Sandwich, &c. its color is nearly white; though I am not without strong suspicion that most of the clay in Plymouth and Barnstable counties belongs to an older deposit, whose type exists on Martha's Vineyard, and which I do not include in the diluvial clays that are described above.

Nearly all the clays in Massachusetts, except the white clay of Duke's County, contain a large per cent. of iron in the state of protoxide. When exposed to strong heat, this passes to the state of peroxide, or the red oxide; and this is the reason why all the bricks made in Massachusetts are red. In some parts of the world bricks are made of clay destitute of iron, and these when burnt, are white, or nearly so. These are denominated fire bricks, because they will endure so powerful a heat without vitrification. The same clay is employed for pipes and white earthern ware; and the most delicate variety is used for the manufacture of porcelain. Very little clay in Massachusetts, except the white variety on Martha's Vineyard, will answer even for

fire bricks; because it nearly all contains iron. The non-ferruginous clay of Martha's Vineyard, however, is quite abundant. I give below its analysis, as well as that of a specimen from an excavation in granite, made a few years ago, a mile northwest of the meeting house in Norwich; where is a vein of blende. The feldspar of the granite is more or less decomposed; and if the quantity is large enough, it will doubtless answer well for the purposes above named; even for porcelain; as its composition corresponds essentially with that of European porcelain clays. In neither of the specimens could I detect a trace of iron: but I selected those which were apparently most pure.

| | (No. 145.) Norwich Clay. | (No. 144.) Gay Head Clay. |
|---|---|---|
| Water, | 8.00 | 9.00 |
| Silica, | 53.40 | 62.26 |
| Alumina, | 36.26 | 29.31 |
| Lime, | 0.24 | 0.18 |
| Magnesia, | 0.68 | 0.45 |
| Manganese, | 0.20 | 0.15 |
| Loss, | 1.22 | Excess—1.35 |
| | 100. | 100. |

Since it is not every white clay that is destitute of iron, as an examination of Nos. 142, 143, will show; it may be well to mention an easy method of determining whether a clay contains iron in the state of protoxide. If it does, it will become yellow, or red, when exposed to a strong heat; but if it does not, its white color will remain.

## *Precious Stones or Gems.*

Although but few gems have yet been wrought that are natives of Massachusetts, yet the list of such as exist there in greater or less quantity, is by no means contemptible.

### *Quartz.*

The most common variety of this mineral, that is employed in jewelry, is the *rock crystal, or pseudo diamond*, which is the limpid crystal. When cut, it exactly resembles pure glass, but is much harder. It may be used for a great variety of ornaments, but on account of its wide diffusion, its pecuniary value is not very high. Although it is met with in almost every part of Massachusetts, I shall refer only to two localities. In the south part of Pelham large quantities of quartz crystals occur, and some of them will answer for the lapidary, (No's. 1097 to 1101.) But these crystals are inferior to those found in the south part of Willamstown, on the farm of a Mr. Phelps. (No. 1987.) The crystals are numerous at this spot, but they are generally of a small size.

### *Yellow Quartz, or Citron, or Occidental Topaz.*

I have met with this variety only at the lead mine at Southampton, and there but rarely. It is said, however, to occur also at Middlefield. When cut it can often hardly be distinguished from topaz.

## *Smoky Quartz, or Smoky Topaz.*

This is quartz crystal that appears as if penetrated by smoke. It makes a delicate ornamental stone when polished. I have found it in crystals in Goshen and massive in Williamsburgh. A coarse variety is not uncommon in large grained granite. I am indebted to J. S. T. Ames Fsq. of Cabotville for a pretty cut specimen from South Brookfield. From Canton in Connecticut, I have a crystal six inches in diameter.

## *Amethyst, or Amethystine Quartz.*

The most valuable variety of amethyst is a violet colored sapphire. But the common amethyst is nothing more than colored quartz. It is met with sometimes in the trap rocks of the Connecticut valley, as on Mount Holyoke and on Deerfield mountain. (Nos. 1192. 1193.) It has been found also in gneiss of a delicate color in Franklin by Mr. Mortimer Blake. (No. 2508.) I have seen it also in rolled masses in Amherst.

## *Rose Quartz.*

This differs only by a shade of color from the amethyst. It would be much esteemed in jewelry were it not that it is liable to fade. Yet a faded specimen may be in a measure restored by being placed for some time in a moist place. This variety occurs in Blanford, Chesterfield, Chester, Williamsburgh, and Chelmsford: but at none of these places is it particularly beautiful. (Nos. 733. to 735.)

## *Prase.*

Prase is only a green variety of quartz, of no great value as a gem. I have noticed it only in bowlders of graywacke in Brighton, Dorchester, and Dover. (No. 391.)

## *Hornstone.*

I know of but one variety of this mineral in Massachusetts that is delicate enough for the purposes of the lapidary: and that is the light green specimen (No. 2509.) from Pelham and Amherst, where it has been found only in bowlders. From the specimen in the state collection, it will be seen that if polished, it would form ornamental articles of rich appearance. This specimen moreover is interesting from its historical associations; it being the identical block out of which the followers of Shays manufactured flints during his insurrection against the Government. I am indebted for it to O. M. Clapp, Esq. of Amherst whose father preserved it. It is fully equal to flint for striking fire.

## *Chalcedony.*

Almost all the varieties of this mineral, viz. common or gray chalcedony, cacholong or the white variety, and carnelian, or the flesh colored, are found in the trap rocks in the valley of the Connecticut, particularly in Deerfield. The specimens, however, are not usually large. But in

the primary regions of the state, and associated with mica slate, we find large rounded masses of chalcedony, which is usually mixed with some other variety of quartz; as at Chester, Tyringham, Conway, and Amherst. Were this mineral in demand by the lapidary, I doubt not but some of these localities would afford handsome specimens.

## *Jasper.*

This mineral, reckoned among the precious stones by the ancients, is not uncommon with the porphyry of the eastern part of the state. Saugus has long been known as its principal locality. Specimens from that place are, indeed, more beautiful than any which I have met with from other parts of the state: though were I writing the scientific history of the mineral, I might be permitted to doubt whether it is the genuine jasper of mineralogists. But as it greatly resembles true jasper, it may, without practical error, be considered such. Its color is red, and sometimes it is traversed by white veins which makes it resemble the striped jasper of Egypt. (Nos. 388. to 390.) Several other varieties of this mineral are found in Lynn, and in the vicinity of the Blue Hills. Indeed, almost all the sea beaches from Boston to Sandwich abound in pebbles of this character From them all a beautiful collection might be made out.

## *Agates.*

Agates are composed of the different varieties of quartz, arranged in spots, veins, or stripes, so as to produce a pleasing diversity of colors. These are not uncommon in Massachusetts. Some have been found in the south part of Deerfield, (No. 1191.) from six to nine inches across, composed of concentric layers of chalcedony, carnelian, &c.: and sometimes these constitute a geode lined with crystals of amethyst. In Conway and Amherst, the different varieties of quartz, such as hornstone jasper, and chalcedony, are agatized; so that if polished they would be beautiful. (Nos. 737 to 745.) In Rochester I have found large masses of a brecciated agate, which admits of a good polish, (No. 1103.) and this occurs more or less in a northerly direction almost to Middleborough: and southeasterly to Fairhaven. I doubt not but some fine specimens might be found in that region.

## *Satin Spar.*

This fibrous variety of limestone, which would be more valued were it harder, exists in considerable quantities in at least two places in Massachusetts. At Newbury it occurs in connection with serpentine, and is of a white color. At West Springfield, it is in veins traversing red slate, which has imparted to it a reddish color. The pearly lustre of this mineral makes it a favorite for the beads of necklaces and for ear-rings.

## *Apatite.*

In color and appearance this mineral resembles several more valuable precious stones; especially the beryl: but it is much softer and consequently much less valuable. It occurs at several places in the State; especially in the limestone beds of Bolton, Littleton, and in the mica slate of Norwich, &c. But I have seen none that would be elegant when cut and polished. (Nos. 531. 728.)

## *Amber.*

It ought not to be forgotten that fragments of this mineralized resin, which makes very pretty ornaments, has been found at Gay Head; and a mass on Nantucket weighing a pound: and that the tertiary deposits of those islands are precisely of the character most likely to yield this substance.

## *Fluor Spar.*

I know of no locality of this mineral in the State that furnishes specimens of much size: But those at the lead mine in Southampton are of a deep green and purple color and beautiful: and should that mine be more extensively explored, there can be no doubt but fine specimens of fluor would be obtained. It is used chiefly for vases.

## *Sappare or Kyanite.*

Good specimens of this mineral are very easily mistaken for the blue sapphire; from which however, it is very easily distinguished by its inferior hardness. In this country it has scarcely been employed in jewelry; but in France and Spain it is cut into forms adapted for rings, broaches, &c. Although not uncommon in this state, the only locality where its color is fine enough for this purpose, is Chesterfield, where it is often found very beautiful.

## *Feldspar.*

Adularia is the variety of this mineral most frequently used in jewelry. It forms the *Moon Stone*, *Sun Stone*, *Water Opal*, &c. In Brimfield, Sturbridge, and Ware, it forms numerous laminar nodules, which would undoubtedly answer well for ornamental purposes.

There are two localities in the State of green feldspar: viz. Beverly and Southbridge. The latter is a light green adularia, and answers well for ornaments; as the polished specimen No. 1086 will show. That found in Beverly is of a still deeper and richer green color.

Some of the feldspars of Essex County, are of other rich colors; as brown, bronze, &c. and it seems to me they would be elegant if cut and polished.

## *Iolite.*

This mineral, which somewhat resembles sapphire in color, occurs in the gneiss of Brimfield. But whether in masses large enough for ornamental purposes, is perhaps uncertain. Yet the locality has yet been but imperfectly explored.

## *Silicate of Manganese, or Manganese Spar.*

This beautiful ore takes a good polish, and is sometimes employed in jewelry for inlaid work. It occurs abundantly in Cummington; but has never to my knowledge been cut and polished in this country, except a few specimens by J. S. T. Ames, Esq.

### *Garnet.*

Two varieties of the garnet of Massachusetts, vie in beauty with those from any part of the world. The first is the essonite, or cinnamon stone; so called from its brown color. Splendid crystals of this mineral are found in the limestone of Carlisle, accompanied by scapolites, actynolite, &c. Without polishing, these crystals form splendid gems. Less beautiful specimens are found in limestone in Boxborough.

The other variety is the Pyrope. And this exists in Worcester county in great quantity, in a belt of country several miles wide, embracing the towns of Sturbridge, Brimfield, Wales, Holland, Ware, Brookfield, Barre, &c. The same garnetiferous gneiss that contains this mineral in Massachusetts, I have traced nearly to Long Island Sound. The most perfect specimens of this pyrope occur at an excavation made in Sturbridge a few years ago, in search of plumbago, on the farm of Mr. Morse, one and a half miles south of the meeting house. These are so fine that I have placed some specimens in the Government collection that have been cut and polished and were they set in foil, they would advantageously compare with pyrope from almost any part of the world. Though the rock abounds with the mineral at this spot, the best specimens are obtained from the thin layers of plumbago which exist there. There is little difficulty in finding specimens large enough and of good color in many places: but they are liable to be filled with fissures. Those in the plumbago have more solidity. I think the time will come when this beautiful mineral will be extensively sought after in the region above described. At present there is no demand for it, because there is not, to my knowledge, a lapidary in New England.

### *Spinelle.*

The blue or black spinelle has no commercial value, not being used for jewelry. But the red spinelle, or ruby is extensively employed. Both varieties have been found at Boxborough, Bolton, and Littleton, in the limestone: but as the red variety is very rare, it is unnecessary to dwell upon the subject.

### *Tourmaline.*

All the varieties of color which this mineral any where exhibits, viz. blue, red, indigo, black and white; and all mixtures of these colors, are found in the tourmalines of Chesterfield and Goshen. These colors too, are very rich: but hitherto the crystals found there have abounded in cracks, which have injured them for cutting; although they form elegant cabinet specimens. Some of the specimens, however, would admit of being wrought. The red tourmaline is said also to occur with the essonite garnet, in the limestone of Carlisle.

### *Beryl.*

The recent discovery of a rich locality of this mineral in South Royalston, enables me to place it as the first and most abundant of all the gems of Massachusetts. The specimens in the State Collection exhibit it in its natural state, as well as cut and polished by the lapidary. When set in gold, it is often much richer in appearance than the common beryl, that goes by the name of *aquamarine*. Its color often approaches nearer to the genuine emerald, though some specimens have the peculiar blue color of aquamarine. Sometimes, though rarely, the color is a yellowish green, very much like the chrysolite. Hundreds of specimens have already been obtained from this spot; and the prospect is, that a vast many more may be obtained. They occur in a vein of coarse granite, 10 or 12 feet wide, traversing gneiss; and the purest beryls are in the quartz. It ought, however, to be remarked, that only a few of the specimens are free enough from fissures to be advantageously cut. Yet considering the large number of fine cabinet specimens that have been, and probably can be, obtained there, I apprehend that no locality of beryl hitherto discovered in this country, can compare with this. My attention was first directed to it by Alden Spooner Esq. of Athol; who generously furnished me with several fine specimens.

Another new locality of beryl, less prolific however, and furnishing far less beautiful specimens, is in the extreme west part of Barre, in a coarse granite vein, similar to that in South Royalston. The State collection contains specimens. Several other localities exist in the State; as, Norwich, Goshen, Chesterfield, Pelham, Warwick, Fitchburg, &c.: and from some of them, now and then a specimen has been obtained nearly equal to those from Royalston: but in general they are coarse and scarcely translucent.

## 4. USEFUL METALS AND THEIR ORES.

I shall begin with the metal that is most wide spread, abundant, and useful.

### 1. *Iron.*

### *Arsenical Iron and Carbonate of Iron in Worcester.*

In the town of Worcester, in mica slate, is a bed of these ores, which was explored to some depth, a number of years ago, in search of the precious metals. A little galena or lead ore is found also, in the same mine. As the excavations are now nearly filled up, it is impossible to judge of the extent of this bed.

Arsenical iron is seldom explored for the purpose of getting malleable iron from it; although it is sometimes employed for the arsenic it contains, and for the preparation of sulphuret of arsenic. The carbonate of iron is an excellent ore: and has received the name of steel ore, because it may be readily converted into steel.

### *Carbonate of Iron and Sulphuret of Zinc in Sterling.*

This is a bed, in mica slate, just like that at Worcester: and was extensively explored forty or fifty years ago, for the same purpose which led to the opening of that bed, viz. the discovery of gold and silver. The carbonate is the most abundant ore, and lies scattered about the excavation, in considerable quantities; although the sulphuret of iron is common, which is sometimes arsenical. A reddish, foliated sulphuret of zinc also occurs here, in considerable quantity, and some sulphuret of lead. Whether this mine will be found worth exploring, it is difficult in its present state, to determine. If it afford the carbonate of iron in large quantities, it will certainly repay the effort. It lies about a mile and a half southeast of the center of the town.

The most important one at the above localities being carbonate of iron, I have subjected specimens to analysis with the following results. From 100 parts of the ore from Worcester (No. 783) I obtained,

| | |
|---|---|
| Silica &c. | 3.66 |
| Proto Carbonate of Iron, | 59.28 |
| " of Manganese. | 1094 |
| Carbonate of Magnesia, | 25.80 |
| Loss, | 0.32 |
| | 100.00 |

A specimen from Sterling (No. 785) yielded,

| | |
|---|---|
| Silica, | 0.69 |
| Proto Carbonate of Iron, | 81.69 |
| " of Manganese, | 4.42 |
| Carbonate of Magnesia, | 12.58 |
| Loss, | 0.62 |
| | 100.00 |

*Carbonate of Iron in West Stockbridge.*

At the bed of hematite iron ore in West Stockbridge, there is frequently found a stone of a light gray color, (No. 1689) which used to be thrown away as of no value. But its great weight attracted attention; and upon trial it was found to be an excellent ore of iron. On analysis I find it to be a granular, almost pulverulent, and quite pure, carbonate of iron. It yielded as follows:

| | |
|---|---|
| Proto Carbonate of Iron, | 87.19 |
| Carbonate of Magnesia, | 5.21 |
| do. of Manganese, | 2.46 |
| do. of Lime, | 1.41 |
| Silica, alumina, &c. | 2.81 |
| Loss, | 0.92 |
| | 100.00 |

This ore exactly resembles a specimen of the Sphaerosiderite from Hesse in Germany,* and can hardly be distinguished from the compact carbonate of iron found in some of the coal fields of this country. If it exists in much quantity at West Stockbridge, or at any of the beds of iron ore in Berkshire County, it deserves the attention of the enterprizing men who are there engaged in the manufacture of iron. But I cannot conceive why this ore should not yield steel at once as is done in the process by which German Steel is prepared. Since I ascertained the composition of this ore, I have not been able to visit the iron deposits of Berkshire.

* This specimen is No. 153 of a collection of rocks from Germany in the Cabinet of Amherst College. As this collection will probably be permanently accessible, I shall for the sake of comparison, several times refer to it in the progress of this report. An Economical Collection from Europe in the same Cabinet will also be referred to, occasionally.

## *Carbonate of Iron in Newbury.*

As one passes from Newburyport to Kent's Island in Newbury, just as he arrives at the northern margin of the salt marsh surrounding the island, he will notice abundant fragments of a white rock, coated over with iron rust. Suspecting it to be carbonate of iron, I obtained a specimen (No. 176) and have subjected it to a hasty analysis with the following results:

| | |
|---|---|
| Carbonate of lime, | 45.67 |
| Carbonate of magnesia, | 8.97 |
| Proto Carbonate of iron, | 21.76 |
| Proto Carbonate of manganese, | 16.10 |
| Silica and alumina, | 3.34 |
| Loss, | 4.16 |
| | 100. |

Specific gravity, 2.94.

The small quantity of iron in the specimen above analyzed, and the abundance of lime and magnesia, leave one in doubt whether it ought not to be regarded rather as a magnesian limestone containing a large amount of iron and manganese. A more important question is, whether, with so little iron, this mineral can be profitably wrought. And yet some of the ores of spathic iron in Europe that are smelted, contain only a little more than 20 per cent. of the carbonate of iron. This ore is regarded in Europe as one of the most valuable of all the ores of iron, especially for the manufacture of steel; the well known German steel being obtained from it: and the character of most of the substances mixed with it in Newbury, especially of the lime, will probably render any other flux unnecessary in working it, unless it be clay. At any rate, as I noticed the quantity of the mineral to be very great at the spot above named, and as I may not have selected the richest specimens to be found there, I have thought it would be best to call the attention of the public to the locality.

## *Chromite of Iron.*

This valuable ore is disseminated in minute grains through most of the serpentine in Massachusetts, west of Connecticut river. But as yet only two places are known where it exists in veins of sufficient quantity to deserve attention. One of these is in a bed of serpentine five miles northwest of the meeting house in Blanford, on the old road to Becket. It occurs there in tuberculous masses, or perhaps a vein, of only a few inches in diameter; and Dr. H. Holland of Westfield informs me that he has ascertained that it contains only about 30 per cent. of the oxide of chrome. But a few miles farther north, in the west part of Chester, near the rail road, and on one of the branches of Westfield river, he has discovered a vein of much greater extent, which bids fair to afford enough of the ore for the purpose of manufactory into the useful chrome salts. Dr. Holland has furnished me with the following description of this ore.

"The chrome ore," he says, "appears only in the eastern portion of the serpentine. I have found three distinct 'out-cropping' veins of the ore, or more properly *couches*, crossing the ser-

pentine, which is schistose and deep green, east and west, from 5 to 18 inches in width. I had a man blast one of the couches, and with a few hours' labor procured some 1200 pounds of the ore. I have one mass very pure of 60 pounds."

"I have tested the mineral as accurately as possible to determine its comparative value, and found it upon analysis, similar to Uralian chromite of iron, giving from 52 to 53 per cent. of oxide of chrome, as it enters into composition, a protoxide. The iron is from 33 to 35 per cent. a peroxide, by calcination: which removed by hydrochloric acid, from the residuum of first calcination, *gave a distinct trace of platinum, as I considered it.*

"Perhaps I might have been mistaken. I was led to notice it, from the fact that platinum is found associated with chromite of iron in Siberia, as well as in the chromite of iron and iron sand of St Domingo. The Chester chromite of iron has been tested by the Messrs. Tieman of New York, practical chemists. When made fine and free from the matrix, silex, alumina and magnesia, as pure as usual for the arts in gross, it is found to yield, like the Maryland and Pennsylvania chrome ore, about 43 per cent. of protoxide of chrome, which combines with the potash."

It is well known that some of the most beautiful paints in use, as the chrome yellow, chrome green, &c. are prepared from this ore. And to such a use it is Dr. Holland's intention to apply the Chester chromite, whenever it can be done profitably. The foreign salts of chrome have till recently been sold at so low a rate, that it has been impossible to compete with them in a country where labor is so dear as among us. But these articles have recently risen in market: and it seems hardly possible to doubt, but that a mine of chromite of iron must ere many years become exceedingly valuable. A few years since, Dr. Holland prepared several salts from the Chester chromite, and he has been kind enough to send me the only parcels of them yet remaining, and I have put them into the collection forwarded herewith. No. 2498 is a specimen of the Chester chromite of iron: No. 221 chromate of potassa: No. 222 chromate of lead, or chrome yellow: No. 223 dichromate of lead.

I have recently subjected to analysis a specimon of the chromite of iron from Chester, presented to me by Dr. Holland; following the rules given by Dumas in his *Chemie applique aux arts, Tome Troisieme, p.* 446. 25 grains yielded as follows:

| | |
|---|---|
| Mineral undissolved by the nitre and potassa, | 1.80 |
| Silica associated with the oxide of iron, | 1.84 |
| do. with the Chrome, | 0.30 |
| Alumina associated with the iron, | 0.16 |
| do. with the chrome, | 1.10 |
| Oxide of Chrome, | 8.00 |
| Per Oxide of Iron, | 11.70 |
| Loss, | 0.10 |
| | 25.00 |

Exclusive of the silica and alumina, the chrome in the preceeding analysis amounts to about 40 per cent; agreeing, as I understand it, with the foregoing statement by Dr. Holland. But if the analysis be reduced to a centessimal standard, (neglecting the loss of the undecomposed residue,) it will stand as follows. I have added for the sake of comparison analyses of the chrome ore of St. Domingo and Baltimore.

| | Chester, Mass. | St. Domingo. | Baltimore. |
|---|---|---|---|
| Oxide of Chrome, | 34.63 | 36.0 | 39.514 |
| Oxide of Iron, | 50.65 | 37.0 | 36.004 |
| Silica, | 9.27 | 5.0 | 10.596 |
| Alumina, | 5.45 | 21.5 | 13.002 |

There is a good deal of diversity in the amount of ingredients in the chromite of iron from different localities. Dumas thinks they can all be reduced to two formulas: the first of which embraces the Chester Chromite:

$$Ch\ O + Fe^2\ O^3$$
$$3\ Ch\ O + Fe^2\ O^3$$

Beudant thinks it necessary to admit at least four different combinations of the ingredients. (*Traite de Mineralogie, Tome Second, p.* 666.)

## *Phosphate of Iron.*

The earthy variety of this ore has been found, in considerable quantity, at the mineral spring in Hopkinton. It forms a bed, one or two feet below the surface, and has been employed as a pigment. It is said to exist also near Plymouth.

## *Sulphuret of Iron, or Iron Pyrites.*

This is the yellow ore so frequently mistaken for gold. It occurs more or less in almost every rock; but it is of no use, unless it exists in large quantities, and is of that variety which easily decomposes. In such a case, it may be converted into the sulphate of iron; that is, into copperas. The ore is broken up, and exposed to the action of air and moisture, when the change takes place, and the lixivium is evaporated to obtain the copperas. In Massachusetts, one can hardly avoid meeting with iron pyrites; and in the western part of Worcester county, the traveller cannot but notice, that nearly all the rocks are coated over with iron rust. This is the result of the decomposition I have spoken of. In Hubbardston, the sulphate is so abundant, that a manufactory of copperas has been established, and I believe success has thus far attended the enterprize. The annual produce is about 75 tons. I should presume that copperas might be manufactured in several other towns south of Hubbardston; as in North Brookfield and Southbridge, although the rocks do not appear as highly impregnated with pyrites in any place as in Hubbardston.

The decomposition of pyrites, in large quantities, often produces a considerable degree of heat; and sometimes pieces of rocks are driven off with explosion. This is one of the sources of those numerous stories which one hears in the country, concerning noises heard, and lights with smoke seen in the mountains. Such occurrences excite the belief of the existence of valuable mines in the vicinity: but they evince the existence of nothing more than iron pyrites.

## *Magnetic oxide of Iron.*

This is a valuable ore, affording from 50 to 90 per cent of iron. It exists in several places in Massachusetts, and on the borders of the State. When pure it contains about 69 per cent. of the peroxide and 31 per cent. of the protoxide of iron.

## *Hawley Iron Mine.*

The principal ore here is the magnetic oxide, which is very good, and the bed is favorably situated for exploration. The ore does not seem to be abundant, the bed being rarely more than one or two feet wide. It has been wrought to some extent; but the operations are at present suspended. Micaceous oxide of iron occurs at the same bed.

The same bed of ore makes its appearance a mile or two south of the excavation: and also, as I have been told, two or three miles north, in Charlemont

### *Beds of Magnetic Iron ore in Chester.*

In the western part of Chester, near the bed of serpentine and soapstone already described, not far from the Western Rail Road, are several beds of magnetic oxide of iron: none of which exceed a foot in width. They occur in the hornblende slate, a little east of the serpentine and soapstone, on the same high hill. Like them, the ore also extends southerly into the mountains towards Blanford. And by looking at the geological map, it will be seen that the talcose slate and hornblende slate formations of Chester extend northerly across the state; and embrace the Hawley iron ore: so that probably it will be found that this ore is common along the junction of these rocks. Indeed I have lately had intimation that in the south part of Hawley, the ore occurs in large quantity: but I have not since had an opportunity to visit the spot.

### *Vein of Magnetic Oxide on Beartown Mountain.*

Mr. Daniel Couch of South Lee showed me a specimen of magnetic oxide of iron of good quality, which he obtained from a vein in quartz rock on Beartown Mountain, near the road to Beartown, and within the bounds of Tyringham. At the surface, the vein was only 4 inches wide: but on exploring it a few feet downwards, it had enlarged to 18 inches.

### *Bed in Bernardston.*

In describing the bed of limestone in Bernardston, I have already spoken of the bed of magnetic oxide of iron, several feet thick, contained in the limestone; and of the attempt made some years ago to smelt it. Both beds dip at a moderate angle to the southeast, and are accessible without difficulty. Although the trials that were made with this ore, were not very successful, yet there can be but little doubt that those trials were very imperfect; and since the ore is abundant, it will no doubt ere long, attract the attention of those engaged in the manufacture of iron. A specimen analyzed (No. 505,) gave the following results:

| | |
|---|---|
| Peroxide of Iron, | 57.86 |
| Protoxide of do. | 25.98 |
| Silica, | 9.90 |
| Magnesia, | 5.42 |
| Manganese, | 0.54 |
| Loss, | 0.30 |
| | 100.00 |

This analysis shows no ingredient in this ore that would resist its reduction, except perhaps the small quantity of manganese; and to conquer this, nothing more is needed than the hot air blast, so commonly used in the country at this day for the reduction of iron.

### *Bed in Warwick.*

Near the east line of Warwick, in a hill of mica slate, are at least two beds of magnetic oxide of iron, several feet in width: but as they have never been opened to any extent, their exact

width is difficult to be determined. There can be no doubt however, that the quantity of ore is amply sufficient for every purpose of the manufacturer. It is very compact; and has a specific gravity of 4.47. Hence it would probably require the mixture of some other kind of ore, in order to be readily reduced. It also contains manganese, which will make it desirable to use the hot air blast for smelting it. I cannot but believe that the want of these, or similar precautions, was the cause why an attempt to reduce this ore several years ago was unsuccessful. At least, the following analysis discovers no other cause for the failure.

| | |
|---|---|
| Peroxide of Iron, | 46.34 |
| Protoxide of do. | 20.70 |
| Silica, | 15.28 |
| Manganese, | 7.92 |
| Magnesia, | 4.18 |
| Lime, | 4.88 |
| Loss, | 0.70 |
| | 100.00 |

I feel confident that the preceding analysis, as well as that of the Bernardston ore, give the per cent. of iron very near the truth. But in regard to the other ingredients, I do not feel quite so sure; because I have not been able to make all the verifications that are desirable. As a ground for judging of the value of the ore by practical men, these results are doubtless sufficient: but for scientific deductions they ought to be repeated.

### *Magnetic Ore Beds on the borders of Massachusetts.*

As much of the ore from these beds is used in Massachusetts, I ought to refer to them. In Winchester, N. Hampshire, a bed exists only two or three miles from Massachusetts, which was formerly worked: and the ore is said to be abundant: but I have not visited it. In Somerset, Vermont, several miles north of Massachusetts, is a rich deposit of this ore, which is very successfuly wrought, and forms beautiful iron. But the largest deposit of this ore is in Cumberland, Rhode Island, two miles northeast of the centre of the town, and of course almost on the line between the states. A large hill is here almost entirely composed of iron ore; and it exists in many other places in the town. I am not aware that this ore has been analyzed: but I apprehend that it will be found to be very much impregnated with manganese. A few years ago I was informed by General Leach of Easton, who then owned this hill, that it did not yield more than 25 to 30 per cent. of metallic iron.

### *Micaceous Specular Iron Ore, at Hawley.*

I have met with the common specular iron ore scarcely any where in Massachusetts. At Malden it is said to exist in small quantity, in porphyry; and in Mendon in granite. And I have seen a specimen blasted from the rail road cut in sienite, in Dedham. Of the micaceous oxide of iron, however, which is a variety of the specular oxide, we have a fine locality in Hawley, where it is associated with the magnetic oxide already described. For cabinet specimens it is very fine, as a reference to No. 844, will show. Formerly this ore was rejected as of no value: though afterwards it was

smelted. And it is indeed an exceedingly pure ore, which must yield nearly 70 per cent. of iron; as the following analysis will show.

| | |
|---|---|
| Peroxide of Iron, | 99.26 |
| Water, (lodged probably between the scales of the ore,) | 0.60 |
| Loss, | 0.14 |
| | 100.00 |

We may safely consider this ore as an absolutely pure peroxide of iron: the oxygen amounting to 30.66 per cent. and the iron to 69. 34. Whether a large quantity of it can be obtained at the mine I could not accurately determine.

### *Micaceous Iron Ore in Montague.*

Near the mouth of Miller's river is a hill of considerable extent, which appears to be traversed by numerous veins of this ore. The largest which comes in sight, is in the southeast part of the hill, at the top of a ledge of mica slate and granite, and is several feet in width. It is favorably situated for exploration, and unless the ore is injured by an occasional mixture of sulphuret of iron, I do not see why it might not be profitably wrought. Wood is very abundant in the vicinity, and it is not far from Connecticut river. Good micaceous oxide of iron, yields about 70 per cent. of excellent iron.

According to Professor Webster, thin veins of micaceous iron ore exist in the porphyry of Malden, which were formerly wrought to some extent. It occurs also in graywacke, at Brighton, and in greenstone at Charlestown, according to the Messrs. Danas.

### *Limonite, or Hydrated Peroxide of Iron.*

In this species are embraced nearly all the iron ores that have been wrought in Massachusetts; viz. the Brown Hematite, the Argillaceous Oxide, and the Bog Ore, with red and yellow ochres.

### *Brown Hematite.*

Connected with the limestone, mica slate, and talcose slate, along the westtern side of the Green Mountain range, in the eastern part of New York, and the western part of Connecticut, Massachusetts, and Vermont, are numerous and extensive beds of the brown hydrate of iron, commonly called *hematite*. This is a most valuable ore; and has been extensively explored in all the states above named; as at Kent and Salisbury in Connecticut, at Amenia, Beekman, Dover, Fiskill, &c. in New York; and at Bennington, Vermont. I am satisfied that the ore usually forms beds in mica slate. But most of those that have been explored are in diluvium; having been removed from their original position by diluvial or alluvial agency. In a few excavations, however, the ore is seen between the layers of the slate. This is a point of no small importance. For if the ore exists only in diluvium, it

may ere long be exhausted. But if the masses in diluvium be only the detritus of beds in the slate, there is scarcely any probability that the ore will ever be exhausted: since we may suppose that it extends as deep into the earth as the slate.

The brown hematite of Massachusetts is confined I believe to Berkshire County. The ore is sometimes fibrous and concretionary, (which are the purest varieties) but more commonly compact or vesicular, and often ochrey. I shall now give a brief account of those beds of this ore whose existence I have been able to ascertain in Berkshire.

To begin with the south part of the County. I have been informed that several hundred tons of this ore were dug some years ago in the south part of Tyringham, and that indications of extensive beds exist there. But I have not visited the spot.

In the west part of New Marlbourough, on the farm of Josiah Sheldon, several excavations have been made a few feet deep, over a space of several acres, and an abundance of yellow and light red ochres extracted; such as usually accompany beds of hematite. I can have little doubt that farther exploration would bring to light an extensive bed of ore.

In Great Barrington, a deposit of this ore exists at the south end of Long Pond, which was formerly wrought to some extent. Another deposit occurs about a mile and a half northeast from the village; and several others exist on the east side of the Housatonic farther south. There can be no doubt that the ore may be found in this town in abundance.

In Stockbridge there are indications of this ore a little distance north of the village, accompanied with much sulphuret of iron.

In Lenox, as many as four or five beds have formerly been opened, and much ore has been carried away. One excavation was made in the village, and several others a mile or two west of the village: so that we have every reason to suppose the soil to abound with the ore.

One deposit at least exists in Alford: but its extent is not known.

In Lee, are indications of several beds; as one can see in many places, where the earth has been excavated a few feet for highways.

A very large deposit has long been explored in West Stockbridge, from which, in 1837, no less than 4000 tons were extracted: which were valued at $2000: and probably this is not far from the average annual produce of the mine.

Judging from what is at present known, Richmond abounds in this ore more than any other town in the county. Not less than 12 beds are known: most of which have been more or less explored. At one of these beds, in the east part of the town, I noticed that the quantity of yellow ochre was very great. At another, in the southeast part of the town, I found the best specimens of the fibrous variety that I had seen in the county. The fibres are several inches long. As this is the purest variety of the brown hematite, I subjected it to analysis with the following results.

| | |
|---|---|
| Peroxide of Iron, | 85 |
| Water, | 14 |
| Oxide of Manganese, | 1 |
| | 100 |

In the northern parts of Berkshire, very few deposits of this ore have been explored. In Cheshire, some years ago, a bed was opened one mile west of the Common, which yielded considerable ore: but it is not now explored. Two or three miles northeast of the north village in

Adams, also, numerous rolled masses of this ore were shown me at the foot of Hoosac Mountain. Some of these pieces were more than a foot in diameter: and I was assured they might be found half way up the mountain. In short, the indications are very favorable of a large deposit in that place. In the south part of Williamstown, also, on land of Joshua Morey, the hematite appears in the banks of a small stream. But without exploration it is impossible to judge of its extent, or value. One mile east of this spot is a bed of yellow ochre, which was formerly explored.

For reducing the ores that have been described in Berkshire, I cannot ascertain that more than four furnaces are in operation. In 1837, according to the returns made to the Secretary of State, the following was the amount and the value of the iron reduced.

| | | | | | | |
|---|---|---|---|---|---|---|
| In Great Barrington, | One Furnace, | Pig Iron, | 180 | Tons, | Value | $ 7.200 |
| In Lenox, | do | do | 500 | do | do | 22.500 |
| In Richmond, | do | do | 600 | do | do | 26.400 |
| In Stockbridge, | do | do | 1337 | do | do | 53.480 |
| | | | | | | $ 109.580 |

It will be obvious from the above statement, that there are probably many deposits of hematite in Berkshire county yet untouched, that might easily be brought to light. And doubtless many others will from time to time be discovered when the attention of discerning men is more turned to the subject. In Richmond, the existence of one of the deposits that has since yielded abundantly, was first made known by the fragments thrown out of his hole by a woodchuck. And wherever the limestone is accompanied by mica slate, as it is through all the valleys of Berkshire, I can see no reason why we may not expect to find the ore, whenever man or beast shall penetrate the detritus that now conceals it.

### *Clay Iron Ore.*

This is the hydrate of iron more or less mixed with clay. It embraces two varieties in Massachusetts, the nodular and pisiform, and the bog ore. The former is found only in the southeastern part of the state; where it is connected with a tertiary formation, which I have considered identical with the Plastic Clay of Europe. Its richest locality is at Gay Head, and its vicinity: where nodules occur, sometimes nearly a foot in diameter, of excellent ore. It occurs there also, with a pisiform structure; and also mamillary. Of the latter variety, the best locality is at Minimshi Bite, about three miles easterly from Gay Head. The ore is so abundant at these localities, and so good, that I am surprised it has been no more sought after. It was, however, used in furnaces on the continent during the last war. Nos. 119, to 123, will give a good idea of the varieties of this ore.

### *Bog Ore.*

This variety of the argillaceous oxide, is more abundant than any other in the State, and has been used extensively in the manufacture of cast iron; for which it is chiefly adapted. In the following towns it is found in large quantities: viz. Groton, North, West, and South Brookfield, Carver, Hopkinton, Hardwick, New Braintree, Oakham, Berlin, Sturbridge, Southbridge, Freetown, Dartmouth, Rochester, Troy, Easton, and Sharon; and in the following, it exists in greater

or less quantities; in Middleborough, Malden, Seekonk, Sheffield, Templeton, Warwick, Williamstown, Greenfield, Northampton, Springfield, Williamsburg, Dalton, Holland, Wales, Norton, Mansfield, Bridgewater, Stoughton, Spencer, Gloucester, and on Martha's Vineyard: indeed, I can hardly doubt that more or less of this ore may be found in nearly every town in the State. I found it so common that at length I ceased to enquire for it, and the localities are so numerous that I have not attempted to exhibit them all upon the Map.

It ought to be recollected, that the process by which bog ore is deposited, is in many places now going on, particularly at the bottom of ponds. The interval between one dredging and another, was so variously stated to me, that I suspect it differs greatly in different places. I presume, however, that it ought never to be put less than twenty years. But the fact that there will be a renewal of the deposit after a certain time, is interesting: because it shows that this mineral will never be entirely exhausted.

### 2. *Lead.*

Several ores of this metal are enumerated by mineralogists, as occurring in Massachusetts; but none is found in sufficient quantity to render it of any statistical interest except the sulphuret, commonly called *galena*: and the most important veins of this species are confined to the vicinity of Connecticut river. No fewer than fourteen of these occur in that region of sufficient importance to deserve notice. All these are in mica slate or granite; or they pass from the one rock into the other.

#### *In Southampton.*

The vein in the northern part of this town has attracted more attention than any other in the region, and has been several times described. It is six or eight feet wide where it has been explored, and traverses granite and mica slate, the matrix or gangue containing the ore, being a mixture of quartz and sulphate of baryta. It has been opened forty or fifty feet deep, in several places, and masses of ore were dug out from half an inch to a foot in diameter. As the vein descends almost perpendicularly into the rock, water soon accumulated in such quantities, as induced the proprietors to attempt reaching the vein by a horizontal drift or adit, from the bottom of the hill on the east side. This was no small undertaking, as the opening must be carried nearly a quarter of a mile into the solid rock. It was persevered in, however, at a great expense, for a distance of nearly nine hundred feet, when one of the principal miners having died, and the price of lead having fallen two or three hundred per cent. all operations were suspended, and I believe the proprietors wish to dispose of the mine. Had they continued this drift a few feet farther, there is every probability that the principal vein would have been struck, from one hundred and fifty to two hundred feet below the surface. Perhaps, however, the work cannot be successfully and profitably resumed

until the market shall cease to be glutted with lead from Missouri; but there can be little doubt, that immense quantities of ore may be obtained at this spot, it may then probably be explored with advantage. I do not doubt, however that those who first examined this mine were mistaken in the opinion that this vein extends from Montgomery to Hatfield, a distance of twenty miles. Lead may indeed be found at intervals along a line connecting those places. But I have every reason to suppose, that it proceeds from several distinct and independent veins.

The principal ore above described is the sulphuret; but there have been found here also, the carbonate, sulphate, molybdate, muriate and phosphate of lead, along with the sulphuret of zinc, pyritous copper, and fluor spar. Mineralogists will greatly regret, that mining operations have been suspended here, because they were anticipating the development of rich specimens of these and other minerals.

Another vein of galena exists in the south part of Southampton, near the line of Montgomery. It appears for several rods on the surface, but is only a foot or two in breadth. A few years ago, efforts were made to open this vein by a horizontal adit, but the proprietors became discouraged and abandoned the undertaking.

*In Northampton.*

This vein is only a short distance north of the principal vein in Southampton above described. The gangue is radiated quartz, and the walls are mica slate. Yellow blende or sulphuret of zinc abounds here: and the vein was formerly explored to a considerable depth. It is several feet wide.

*In Westhampton.*

This vein has been usually described as existing in Williamsburg and extending into Northampton. But so far as it exhibits itself at the surface, it lies wholly in Westhampton—in quite the northeast part of the town, only a few rods from the Northampton line, and but half a mile from that of Williamsburg. The gangue is quartz, and the vein is several feet wide, and may be traced 30 or 40 rods. But the quantity of galena is small at the surface.

*In Williamsburgh.*

A vein of galena lies in the northeastern part of this town, and probably extends into Whately. It is two or three feet wide, and the gangue, as in nearly every other vein of lead in this region, is quartz. Manganese is found in the same gangue.

A second vein of quartz with galena occurs in this town, a mile or two northeast of the one last mentioned. The quartz, however, appears only in loose masses on the surface, but to such an extent, as can be explained only on the supposition, that a vein exists in the rock beneath the soil. Pyritous copper is found in connection with the galena at this place.

*In Goshen.*

According to the statements of Mr. Alanson Nash, who has given a map and description of the lead veins and mines of Hampshire county, in the twelfth volume of the American Journal of Science, the same indications of a galena vein appear a little west of the centre of Goshen, as those mentioned in respect to the third vein in Williamsburgh just noticed, viz. the occurrence of masses of quartz containing galena. The rock in the region is mica slate and granite.

*In Whately.*

In this town are three distinct veins containing lead. One is about half a mile east of the first vein described in Williamsburgh It extends a short distance into Whately. In its whole course, but particularly at its southern part, it contains oxide of manganese along with galena.

A second vein, three or four feet wide, exists in a high ridge of granite towards the southwest part of the town. It may be traced along this ridge about three quarters of a mile.

The third vein is in the northwest part of the town, extending some distance into Conway. Galena, in quartz, is the only ore that appears on the surface. The width of the vein is six or seven feet, and it traverses both granite and mica slate. It runs along the western margin of a high hill, so that if it should ever be explored, a lateral drift could be easily made.

*In Hatfield.*

About two miles west of the village in this town, we find a vein of sulphate of baryta, from one to four feet wide at the surface, running in a northwesterly and southeasterly direction and containing galena. A shaft has been sunk in two places from fifteen to twenty feet deep: and the vein was found rapidly to widen in descending. The immense quantity of baryta found here, gives the locality a peculiar interest to the mineralogist.

*In Russell.*

On the hill southwest of Westfield river near Gould's mills in Russell, is a vein of quartz from 2 to 4 feet thick, traversing the granite and mica slate,

and containing galena, blende, and copper pyrites. At the surface the ore is rather sparingly disseminated through the rock. The vein runs nearly north and south, and descends into the hill perpendicularly. The spot where it appears is from 200 to 300 feet above the river, and favorably situated for mining operations should it be thought desirable to undertake them.

### *In Leverett.*

Although this town lies on the eastern side of Connecticut river, yet the granite and mica slate, occurring there, exactly resemble the same rocks found on the west side of the river ; and there can be no doubt that both belong to the same general formation. Two veins, the ore being chiefly galena, are found of precisely the same character as those on the opposite side of the river. That in the southwest part of the town is in granite, not more than a foot or two wide at the surface, and the gangue is sulphate of baryta. The other is a mile and a half to the north of the first: the gangue is quartz, and there is almost an equal quantity of galena and pyritous copper; blende also occurs in small quantities. This vein is several feet wide, and runs through granite and mica slate. Both this and the one first mentioned, have been explored to the depth of a few feet.

It is impossible to form any confident opinion as to the probable quantity of lead, which is contained in the several veins which have been described, except, perhaps, in regard to that in Southampton, which has been explored to a considerable extent and is probably the master vein. In many instances appearances at the surface are quite favorable; but whether the veins become wider, like that in Hatfield, or narrower as they descend, can be determined only by actual exploration. Of one thing, however, I think we may be assured, from the facts that have been stated; viz. that the central parts of Hampshire county contain extensive deposits of lead, which may be of great value to posterity, if not to the present generation. Probably many more veins will hereafter be discovered, since little examination has been made with a view to bring them to light.

### *In Alford.*

On mile north of the centre of Alford is a vein of quartz, several feet wide, traversing limestone, and containing galena and iron pyrites. The vein is not very well defined, and being also much hid by soil, I cannot speak with much confidence as to its actual width. The formation is obviously of the same character as that containing numerous veins of galena in Columbia and Duchess Counties in New York. Prof. Mather states that most of these are situated near the junction of limestone and slate rocks. Slate rock is near the vein in Alford. The only vein in New York that has been extensively wrought, is the Livingston mine in Ancram. This is said to be highly argentiferous, producing 118 ounces of silver to the ton. (*Second Report of the New York Geologists for* 1837 *p.* 176.) I have made no trial of that from Alford to ascertain this point.

### *In Uxbridge.*

On land of Chilon Tucker, in the south part of Uxbridge, galena in small quantity is found in quartz rock: but whether it constitutes a distinct vein, or is disseminated through the rock, I could not certainly determine. The quanity at the surface is small, and the appearances do not indicate a large deposit. The rock, which is stratified, runs N. E. and S. W. and dips 25° S. E. It has been blasted only a few feet in depth. This ore is highly argentiferous, and on this account may deserve attention.

### *In Dedham.*

In the south part of Dedham bowlders of quartz containing galena, occur in considerable quantity: 100 pounds or more of the gangue have been obtained. These facts I state on the authority of William Ellis, Esq. of Dedham who gave me specimens of the ore. But I was disappointed in my intention of visiting the spot, and can add nothing more.

## 3. *Copper.*

This valuable metal occurs in numerous places near the junction of the greenstone and sandstone, in the valley of the Connecticut, between New Haven and Vermont. Several veins of copper ore are found in Connecticut; near the junction of the two rocks, and two of these have been explored extensively: viz. one in Cheshire, which gives much promise, and another in Granby. The latter has long been known under the name of Simsbury mines, although it is within the limits of Granby. Many years ago, before the war of the revolution, I believe, this vein was explored to a considerable extent. Afterwards the government of Connecticut made use of the abandoned shafts and galleries for a State Prison. Since the removal of this prison to Wethersfield, the exploration has been resumed, by a new company, and, as I am informed by the agent, with success. The principal part of the ore, according to Prof. Shepard, is the vitreous copper, associated, however, with green carbonate and variegated copper.

### *In Greenfield.*

In the northeastern part of this town, on the banks of Connecticut river, are two veins of copper ore about a mile apart: the most northern one being about one hundred rods below the mouth of a small stream, called Fall River, and the same distance in a direct line form the cataract in Connecticut river, sometimes called Miller's Falls; but lately, and more appropriately, Turner's Falls. These veins are several feet in width, and they pass into a hill of greenstone on one hand, and under the river on the other into sandstone. The gangue is sulphate of baryta and toadstone, and the

ores are the green carbonate of, and pyritous copper. Actual exploration alone can determine whether these veins might be profitably worked.

On the most southern of the small islands, in the middle of Turner's Falls, has been found a vein of pyritous copper, of a rich quality, and in considerable quantity. Indeed, several varieties of the sandstone rocks in the vicinity, appear to be considerably impregnated with copper.

Pyritous copper is associated with iron, in a vein, in greenstone, at Woburn; but not, probably in a sufficient quantity, to be worth mining. At several places in Cumberland, R. I., where excavations were formerly made, are found gray oxide of copper and pyritous copper with the green and blue carbonates.

### 4. *Zinc.*

The sulphuret of this metal exists in considerable quantity in some of the veins of galena that have been described in Hampshire county. In a vein especially, a mile northeast of that in Southampton, which has been so extensively explored, blende appears to be the principal ore. This spot has been dug several feet in depth, and a good deal of rubbish thrown out along with good specimens of zinc. But I believe this ore was not used.

#### *In Norwich.*

About a mile northeast of the meeting house, near the center of Norwich, Quartus Angell has opened a vein of quartz containing blende in coarse decomposing granite. The specimens of quartz are sometimes elegant; but I noticed no other ore at this spot except the zinc. The exploration was several feet in width and depth; but being partially filled with rubbish, I could not ascertain the width of the vein. I presume it will be found to contain some galena, though I saw none.

#### *Cadmia.*

A deposit forms in the chimneys of the iron furnaces in Berkshire county (I noticed it particularly at Richmond and Van Deusenville,) several inches thick, which analysis shows to be almost pure zinc. This must exist in the iron ore, and be sublimed by the heat. No use, as I could learn, has hitherto been made of this substance, which has received the name of *cadmia*. But it would certainly answer an excellent purpose in the manufacture of brass.

### 5. *Manganese.*

In a metallic state this mineral is of no use; and indeed, it is reduced to that state with great difficulty. But in the state of oxide, it is extensively employed, both to remove color from glass and to impart colors; also in painting porcelain and glazing pottery, and still more extensively within a few years, in the manufacture of the chloride of lime, now so generally used in bleaching.

At least two ores of manganese abound in the western part of Massachu-

setts. It has been already remarked, that more or less of the gray oxide exists in the iron beds of Berkshire, and Bennington, Vt. In the vicinity of Connecticut river, however, or rather on the eastern slope of Hoosac mountain, distinct veins and beds of manganese are found.

### *In Plainfield.*

Beds of the oxide of manganese occur in two places in this town, one a mile west of the center, and the other near the southwest corner of the town; and both in talcose slate. Two ores are associated at both these places, viz. the common gray or black oxide and the silicate; the former investing the latter as a black crust, and most probably proceeding from its decomposition; while the latter, when newly broken, is of a delicate rose red. I suspect that the silicate predominates at these places; and from these beds, probably came by diluvial action, those numerous rounded masses of the same in the vicinity of Cummington meetinghouse; although a deep valley intervenes, and the distance is three or four miles.

An attempt was made, some years ago, to explore one of these beds, under the impression that the ore was iron. But how extensive either of them is, it is difficult to determine, as each seems to consist of a number of small beds, or rather the ore is interlaminated with the slate. The occurrence of so much siliceous oxide at these localities, is very interesting to the mineralogist, because this ore is rare in Europe.

### *In Conway.*

A distinct vein of the black oxide of manganese several feet wide occurs in the southeast part of this town, the gangue being quartz. It has not been explored at all; nor is the manganese ore very abundant at the surface. I do not doubt, however, that it may be found here in large quantities.

### 6. *Tin.*

I am able to say with perfect confidence that this interesting metal exists in Massachusetts: but can add little more. I found only a single crystal of its oxide, weighing 50 grains. But this I dug myself from a block of granite in the northwest part of Goshen, and on reducing it to metallic tin, it corresponds exactly in every respect with that metal from England. I have never been able to find any more specimens; but it ought to be borne in mind, that in England, according to a geological writer of that country, "it is generally in the vicinity of a vein of tin ore, that disseminated grains of tinstone are found in the rock."

Mohs, in his Mineralogy, mentions that some small crystals of tin were found in specimens sent to Europe from Chesterfield, Mass., and Prof. Shepard informs me that he has found small crystals in the green feldspar rock of Beverly; and also in the granite of Connecticut.

### 7. *Silver.*

No silver has yet been found in the state, except the small quantity that is usually contained in lead ore. In the galena at Southampton it occurs in the proportion of about 12 1-2 ounces to the ton: a quantity hardly worth the labor of separating. As already stated it exists also in the galena of Uxbridge. The ore from other localities I have not examined for want of time.

### *Misguided Efforts after Gold and Silver.*

Were the history of the wild and ill-directed efforts that have been made, even in Massachusetts, in search of the precious metals, to be written, it would furnish at least important warning to others; and therefore I shall state a few facts on the subject.

The large quantities of the precious metals carried to Europe from South America, soon after its discovery, naturally produced some expectation of finding similar treasures here. But I cannot learn that our forefathers expended large sums in making excavations, where there was no reasonable prospect of finding anything valuable. It was reserved for their descendants to exhibit a credulity and superstitious ignorance on the subject, that are both lamentable and ridiculous.

Perhaps at the present day, a belief in the mysterious virtues of the mineral rod, is the most common of these delusions. Probably many of our intelligent citizens can hardly credit the statement, that there are men in various parts of the State, who profess not a little skill in this enchantment, and are not unfrequently sent for, one or two day's journey, to decide whether there be ore or springs of water in a particular place. In general, but not always, these professors of divination belong to the most ignorant classes in society; for not long since, a venerable and respectable man of good education, sincerely thought it his duty, occasionally to peregrinate with his divining rod, because *it would work in his hands;* and not a few intelligent men have a secret belief, that the branches of a witch hazel are attracted downward towards mineral substances, when in the hands of a certain individual.

The following train of circumstances often takes place. A man, ignorant of mineralogy, finds upon his farm, a specimen of iron pyrites, or yellow mica, or galena, which he mistakes for gold or silver. Even if he shows it to a mineralogist, and is told that he is mistaken, he suspects that his informant is deceiving him, in the hope of getting possession of the prize himself.

He resolves to begin an excavation. And he sees enough in the shining particles of mica and feldspar that are thrown out, to buoy up his hopes, until his purse is well nigh drained.

It was probably in some such way, that the excavations were made in Worcester and Sterling, at the mines of arsenical iron and carbonate of iron; although, in these cases, there would be sufficient ground for examining some of these ores, since they do sometimes contain silver. But I cannot conceive why such extensive excavations were made, when a chemist might have easily settled the question as to their nature, by analyzing 100 grains of the ore, unless it was on the erroneous supposition, which I find to be common, that metallic veins generally become much richer and larger, and even change their contents, as they descend into the earth.

The decomposition of iron pyrites, producing heat and sometimes explosion, is supposed by some to be a strong indication of mineral riches in the earth beneath. The man of the witch hazel rod is called, and if he confirms the suspicion, as he usually will, the excavation is commenced; nor is it suspended until a heavy draft has been made upon the man's pecuniary resources. An extensive excavation was made, many years ago, I am told, in Hubbardston; and from the character of the rock there, I suspect that pyrites gave the first impulse to the undertaking. In Pepperell, an individual has been engaged for several years, in pushing a drift into the rocks, which he has penetrated eight or ten rods; although individuals who have visited the spot, (I have not,) can discover nothing but iron pyrites.

In the year 1815, an individual succeeded in getting a company formed and incorporated with a capital of eighty thousand dollars, called the Easton lead and silver mining company. The fruits of their labor may be seen in an excavation, in red granite nearly one hundred feet deep, at present nearly filled with water. I could not find a particle of ore, of any kind, in the fragments blasted out. A final stop was put to the work, by the killing of two men in blasting.

Forty years since, a shaft was sunk in Mendon, in search of the precious metals. A little specular oxide of iron occurs at the place.

Not long since an individual called upon me, with specimens of black blende or sulphuret of zinc, found in a neighboring town, and which he strongly suspected to be silver. I informed him of its true nature, and seeing that the vision had got strong hold upon his mind, I did all in my power to persuade him not to engage in searching for the ore. But the only effect was to stimulate him to commence an exploration with more ardor. The zinc was found in a loose piece of rock lying in the field. The man's impression was, that even if that ore was of no use, it indicated something valuable beneath. Accordingly he commenced digging. Ere long his faith

was strengthened, by some one's discovering a light, during the darkness, near the spot; and the last I heard from the man, he had penetrated the soil about seventy feet.

A year or two since an individual, apparently respectable, from the western part of New York, called upon me on his way to a neighboring town, in the sanguine expectation of finding there a vein of silver or gold. For his ancestors had owned land there, on which they were confident such a vein existed; because an Indian was said once to have obtained pure silver from it: but would not reveal the spot. However, this individual in some way or other, had got, as he supposed, a clue to the spot; and had performed a journey of several hundred miles, solely to visit it. After a few days he returned, bringing as the fruit of his research, a little iron pyrites (fools gold) and silvery mica. He acknowledged that he had failed entirely in his object; but did not therefore despair of ultimate success, when he should have obtained more specific directions from those who knew the precise spot. Probably in a few years this hopeful enterprise will be resumed.

In very many of these mineral dramas, I find an Indian to be an important and necessary character. And it is curious to notice that he always acts the same part. He is represented as having cut out a piece of the pure lead, or silver, while engaged in hunting; and although ready to exhibit the trophy, he always refuses to point out the spot until perhaps on his death bed, or for a large reward. So many times have I heard this story told with scarcely a variation, that as soon as the Indian is mentioned, I always know the sequel. Now, although every tyro in mineralogy knows that neither silver nor lead occur in but small quantity in a metallic state, and that no Indian is enough of a metallurgist to reduce their ores, yet it is usually useless to state these facts to men who know too little of chemistry to appreciate them. In short, of all the superstitions that prevail among men, those relating to the discovery of the precious metals, are the most difficult to eradicate.

The following case has been stated to me on such authority that I doubt not its correctness.

Some forty or fifty years ago, a farmer, residing not far from the center of Massachusetts, knocked off from a rock upon his farm, a piece of ore, which he sold in Boston for a considerable sum, as a rich ore of silver. From that time to the day of his death, he searched in vain for the rock from which it was broken. The inference which he drew from his ill success, was, that Satan, (who is thought, by multitudes, to have unlimited power over the mineral treasures of the earth,) had concealed or removed the precious vein. Conceiving, however, that some of his posterity might have more interest with that personage than himself, he reserved to them the right of digging the ore, in the instrument which conveyed away his title to the land. His posterity were not forgetful of the reservation; but they were convinced it would be of no use to them, unless they could meet with some individual who had *entered into a league*, (as the phrase is with the class of people whom I am describing,) with his Satanic Majesty. At length they heard of such a man, a German in Pennsylvania, who had obtained possession of a wonderful glass, through which he could discover whatever lies hid beneath the soil. The German was persuaded to visit the spot, and when I passed through

the place, an excavation was about to be commenced under his direction. And I have since been told that the work was prosecuted till the owner's property was well nigh expended.

Still more ridiculous than the opinions and practices above mentioned, are some still existing in a few places in the State, relative to deposits of money, said to have been made by one Kidd, a celebrated buccaneer of early times. The statement is, that he frequently ascended our streams a considerable distance, and buried in their banks, large sums of money. These are supposed to be guarded with sleepless vigilance by the personage mentioned before. But by the use of certain incantations, while digging for the treasure, it may be wrested out of his hands: for instance, perfect silence must reign during the operation, unless it be broken by the reading of the Bible, and all must be done in the night. The last instance of the practice of this mummery, which I have heard of, occurred a few years since on one of the branches of the Westfield river. A hundred day's work were expended upon the enterprise before it was abandoned. At one time those employed in this work were greatly discouraged, by the intrusion of my informant, who in spite of all they could do by gestures, broke silence and thus dissolved the charm. At another time, courage was revived by finding an iron pot, containing some bits of copper, deposited there, the day previous, by some boys, who had learned what was going forward.

For the following statements I am indebted to Dr. Lyman B. Larkin of Wrentham, in a letter of June 5th 1840.

"Report says, that about eighty years ago, when there was so great a gold digging epidemic in nearly all the State of Massachusetts, the people of Wrentham were in some mysterious manner informed that thousands and thousands of the precious metals lay buried beneath their soil.

"The place over which hung the greatest mystery, was on a hill in the southwest part of the town, within sight of the road from Boston to Providence, about four miles from Wrentham center.

"It seems that for several months previous to the time referred to, many dark stories had been circulated in regard to the place, such as strange noises heard, lights distinctly seen several nights &c. &c : also that some one, had found a wedge of gold : though what had become of it no one could tell : but at this time, when every mind was prepared to believe almost anything, and especially that which was most absurd, and when all eyes were turned to the place as being a great storehouse of treasure, one dark and lowery night, a report, like the discharge of a musket, was heard across the swamp from the Providence Road, upon the side of the mineral hill, which arrested the attention of some one from the road, and on turning his eyes that way, he saw a light in a certain spot, which was at once pronounced to be the place where the treasure was to be found. The neighborhood was soon rallied, in search of the place. As I am told, no one had courage to stay behind. The light continuing to shine, directed them to the very spot where they wished to go : but just before they reached it, the light grew more and more dim and finally vanished. But what was most mysterious was, that, though it was quite soft and muddy about the place, there were no tracks. This was sufficient, as all agreed, to show that his Satanic Majesty was there in person, inspecting his mineralogical Depository ; and it was agreed on the

spot to form a company and commence digging. They sunk a shaft to the depth of between 70 and 80 feet, the greater part of which was in a solid rock: and found nothing except a few fragments of a cubical form, resembling gold in appearance, which would burn on being placed in hot coals. Iron pyrites is now found in the same rock, where they are digging for coal.

"After spending an immense sum, all gave up their operations for the want of funds, save the owner of the farm, who being more and more confident from day to day that a great treasure was there, continued to excavate till he had run out his farm and was obliged to sell. He, like the Alchemists, had millions almost in his possession: yet was compelled to sell all he had, to buy a little bread to keep himself and family from starving.

"The farm was sold to Mr. Abijah White, whose son lives upon it now: and in deeding away the place, Mr. Wellman, reserved the privilege, for his posterity, at any time when they should become able, to dig for gold or silver any where upon the place. And within the last four years, one of the grandchildren, Joseph Wellman, came to Mr. Howard Mann, to let himself by the month to dig for gold, promising that Mr. Mann should have a certain part of all that was found. About that time I visited the spot, at Mr. Mann's request, and the conclusion to which we came was, that it was a coal region, and that it might be an object to dig for coal. Mr. Mann then made an agreement with Wellman to dig by the month; but just as he was about to commence, he was taken sick and has done nothing about it since. But I presume he would not sell his right to dig on that farm for half its value.

"The other case of which I gave you an account, was in Dedham, on a farm owned by Mr. Rhodes. In this case they were after Capt. Kidd's money. It seems that in some way or other it was ascertained that there was a large amount of his money there, and a company was formed to dig for it, who sent a committee to make a bargain with Mr. Rhodes the owner of the land for the right to do it.

"Their instructions were to make an agreement, cost what it might They at length proposed to fill Mr. R's grist-mill trough with dollars, (the trough was reported to hold four or five bushels,) for his proportion. Mr. R. declined taking it, preferring rather to have his share of what they found. Upon this they continued to dig in various places on the farm for several months, until the whole Company had spent their property, when they finally gave up the search; and Mr. R. from a comfortable farmer miller, became a poor man.

"This account I had from Mr. Eliphalet Rhodes, a grandson of the owner of the place: and he states these facts to have occurred upwards of 75 years ago.

"At this enlightened age, one would suppose that such ridiculous notions would be given up: but within the last four months, a young man belonging to this town, has secretly commenced digging for the precious mineral. He succeeded in finding the largest quartz crystals which I have ever seen. One of them, I should judge, would measure about 12 inches in circumference. When I stated to him that they were of little pecuniary value, and yet manifested a desire to obtain one of them, his suspicions were excited that I was deceiving him, and that they were ominous of golden treasures at the place. I tried to persuade him to relinquish his design. But this only made him more confident of success, and if I am correctly informed, he went directly to Boston for *disinterested advice*. He has not however resumed the exploration since his return."

I have given these rather mortifying details, partly because I doubt whether one tenth of our population are aware of the existence of such opinions and practices among us; and partly in the hope that the exposition may be instrumental in entirely eradicating them from the minds of those who have been thus deluded. For, like night fogs, they need only to be brought into the light of day to be dissipated.

## 5. SUBSTANCES USEFUL FOR VARIOUS PURPOSES.

A variety of mineral substances, too miscellaneous in their characters and application to be very systematically arranged, will be described under this general title.

### 1. *Materials for Roads.*

A good roadstone should be both hard and tough. Hence a large portion of the state is destitute of such material: for these two qualities are rarely combined in granite, gneiss, mica slate, limestone, or common sandstone. Sienite, which contains a good deal of hornblende, is better: porphyry, and especially compact feldsdar, is very good: as is also that hard quartzose slate which is associated with graywacke. This last is a good deal employed upon the roads around Boston; but must be limited to that vicinity, since it does not occur in other parts of the state, not even in the extensive deposit of graywacke in Bristol and Norfolk Counties. Upon the whole, probably greenstone is the best material for roads in the state; especially when we consider that it is very widely diffused. Around Boston, and in Essex county, as well as in some parts of Norfolk, it is common: and it is scattered more or less over a large part of Worcester county, in bowlders proceeding from numerous limited deposits: though this rock is usually confounded with fragments of dark colored gneiss; especially when the two rocks are coated with lichens. In the valley of Connecticut river, a range of greenstone, admirably adapted for a roadstone, extends nearly across the whole state. In Berkshire county, several varieties of quartz rock will probably serve as a good substitute for greenstone; though I am not aware that hitherto any of the roads there have been dressed with this material, except as nature has dressed them, in the form of pebbles:—a kind of dressing with which the traveller would very gladly dispense. The same is true in most other parts of the state: that is, the roads have not been coated with rocks pounded into fragments. But as more cost and labor are devoted to the roads, this will undoubtedly be done; and it is desirable to know where are the best materials.

In the bed and on the banks of the Merrimac, from Chelmsford to Newbury, is a hard slate approaching quartz rock, which I apprehend will answer nearly as well for a road stone as the slate around Boston associated with the graywacke.

At present, in the interior of the state, roads are usually improved by spreading over them some material already in a finely divided state, which shall form a harder basis, when trodden down, than the soil through which the road passes. The material must of course vary with the nature of the road. Clayey roads, for example, are very much improved by a coating of fine gravel; and sandy roads, by a coating of clay. In the vicinity of Connecticut river, the decomposition of the red slaty sandstone, and especially the calcareous diluvium, in Springfield and West Springfield, form an excellent covering for roads that are too sandy. The iron and calcareous matter cause the argillaceous matter to become hard, especially in the summer, and the track is often made as smooth as a rail road. Could such a material be discovered in the southeastern part of the state, it would be a great acquisition there for improving the roads, which are so sandy Especially would it be desirable that the principal road from Plymouth to Barnstable now the most tedious in the state, should be thus improved. Might not clay enough be found at the cliff forming the north end of Manomet Hill, for at least a part of the work?

### 2. *Firestone.*

Whenever it is desireable to construct a furnace for smelting metals, burning limestone, and the like, it becomes an important enquiry whether a rock can be found in the vicinity that will bear

powerful and long continued heat. Such rocks are called *firestones:* and I have sought anxiously to find them in Massachusetts; not I trust without some success. But in respect to some of the localities, as they have not hitherto been known, no trial of importance has been made of the power of the stones which they produce to resist heat. I infer them to be firestones from their external characters—that is, their resemblance to real firestones.

A good firestone requires a union of qualities which is not very common. To answer well for a furnace, a rock must not only be infusible, but not liable to crack and exfoliate. Hence the presence of lime and magnesia, except as silicates, is unfavorable; and although pure quartz resists fusion well, it is liable to crack. On the other hand, some stones contain so much of potassa, or other easily fusible mineral, that they are converted into glass. The rock that has been most extensively used in the furnaces of Berkshire, and with most success, is a finely granular quartz, in which a small quantity of mica exists in layers. Its coherence is rather feeble. It is found in great quantities in the towns of Washington and Tyringham. (No. 2010.)

The talcose slate of the Taconic range of mountains has sometimes been employed for the lining of furnaces: as at Van Deusenville; and it will probably answer a good purpose. Some varieties of gneiss, that abound in arenaceous quartz, as at Southbridge, are used where strong heat is to be withstood. The micaceous sandstones are also employed for the same purpose; and the red sandstone in the vicinity of Connecticut river appears to be a very good firestone: as has been shown at the lime kiln in Whately.

A beautiful variety of mica slate, in which the layers of quartz and mica are of extreme thinness, occurs in Stafford in Connecticut: and enjoys a higher reputation than any rock in New England as a fire stone. I have lately succeeded in detecting this range of slate across the whole of Massachusetts; and have felt authorized in representing it on the map as continuous; although I have found it in place only at intervals. With the exception of some loose fragments in the west part of Monson, the first point where it appears in place, is on the north shore of Chicopee river, in Palmer, near the rail road, and about 100 rods east of Sedgwick's tavern. The road from Worcester to Springfield, passes close by a ledge on its south side, which there forms a hill 200 feet high. The greater part of this rock is probably too quartzose for firestone: but I doubt not that some of it in the hill would answer well. About three or four miles farther north than this spot, and a mile west of Palmer center, this slate shows itself: but there it is the common mica slate. The next point in proceeding northerly, where we meet with this range, is in Enfield. The high hill a little southwest of the village is composed of it. On its west side, whence stones have been obtained for building one or two factories, the rock is made up mostly of a dark gray arenaceous quartz, with mica sparingly interspersed. (No. 2078.) Some of this rock would probably stand fire well. But upon the top of the hill, extensive ledges appear, of a mica slate very much resembling the firestone from Stafford. (Compare No. 818 with Nos. 2071, 2072, 2073.) It is my belief that excellent firestone may be found in this hill: although some of the rock contains rather too much quartz. But the deposit is very extensive; reaching two miles at least south

of the village. It certainly deserves a fair trial, which it has never had. Nor can it be supposed that I should be able to find, in an examination of an hour or two, where only now and then a ledge appears, the specimens best adapted to the purpose of firestone.

The next spot north of Enfield, where I have found this range of slate, is in the east, and especially the northeast part of Wendell. But I have not carefully examined the intervening distance. In Wendell I saw none but the dark variety of the slate, some of which, however, is very arenaceous. But after passing Miller's river, in the direction of Warwick, the white variety appears in great quantity: and continues at least as far as the middle of Warwick, beyond which point I have not attempted to trace it. At Warwick the range passes about 100 rods east of the centre of the place, and may be traced easily all the way from thence to Orange. Upon the whole, I cannot doubt that this range will furnish, at no distant period, an abundance of excellent fire stone. But numerous trials will be necessary to ascertain the best varieties. I cannot hope to do more than to call the attention of those concerned to the localities.

There is one other locality of firestone in Massachusetts, viz. in Bellingham, which will be more particularly described in the next section.

### 3. *Whetstones and Grindstones.*

The whetstones that have been dug in Massachusetts have all been obtained from an arenaceous variety of mica slate: at least, all the quarries that have fallen under my notice were in rock of that character. Such is the rock in the northwest part of Norwich, where formerly a good many whetstones were manufactured. From the firestone deposit in Enfield, already described, a considerable amount of these stones have been for a long time annually wrought. Smithfield, in Rhode Island, has long been well known for producing whetstones: and they are obtained from a rock which I formerly mistook for talcose slate; but I am now satisfied that it is a delicate mica slate. The stratum of rock which produces them, extends northerly into Bellingham in Massachusetts; and in the northeast part of that town, on the farm of David Adams, it is so well developed, that it has been extensively quarried for whetstones. These are not considered equal to those from Smithfield; yet they answer well for sharpening shoe knives; and in 1838, not less than 22 800 were got out. The scales of mica in this rock, (Nos. 2104 to 2110,) are so fine as scarcely to be visible without a glass, and the rock might be mistaken for argillaceous slate. In Rhode Island it has been employed as a lining for furnaces; and that in Bellingham will undoubtedly answer well for the same purpose.

The only rock in the state which will answer much purpose for grindstones, is the sandstone in the valley of Connecticut river. As yet however, it has scarcely been applied to this purpose; though I have sometimes seen a rather coarse red variety, such as is got out at Hoyt's quarry in Deerfield, used in this manner. If not too liable to disintegration, I should suppose the red stone, composed entirely of grains of siliceous sand, quarried in Longmeadow, would answer well, where it is desirable to wear steel away rapidly. I shall mention only two localities where I suspect a good light gray stone for this use may be found. One is in the north part of South Hadley, near the Artesian Well, (at Hale's Mill) and the other on the north bank of Agawam river, a little

west of the village of West Springfield: (No. 171.) These rocks a good deal resemble the grindstones brought from Nova Scotia: yet where they have been long exposed to the weather, they are harder than the Nova Scotia rocks. But it ought to be recollected, that rocks are usually much harder at the surface than a little distance beneath it.

## 4. *Flagstones.*

Three things are important to form good flagstones: first that the rock should split into thin layers: secondly, that these layers should be even and smooth without hammering: and thirdly that its texture should be close, so as to resist atmospheric influences. Hence, first rate flagstones are not common. In Massachusetts quarries of this kind have been seldom sought after: as the demand has not been great in those parts of the state where they are most likely to be found. I shall mention only a few quarries that have been opened, and a few spots where I suspect they might be opened with advantage.

The most perfect flagstone that I have seen in the state is a variety of quartz rock in Berkshire County. Its principal quarry is in Washington, five miles southeast of Pittsfield. Large slabs can be split out, whose surface is perfectly even, and as smooth as if wrought with the utmost care. This rock occurs also in Tyringham, Lee, and other places.

The mica slate and talcose slate of the mountainous region lying west of Connecticut river, might furnish a large amount of excellent flagstones: as is evident from the numerous fine slabs which the traveller sees, forming the doorstones, and hearths of the farmer's houses in that region. Some quarries have been opened, as in the west part of Goshen, where the stone is fine enough to be employed without hammering for hearth stones. The mica slate, talcose slate, and hornblende slate, along the Western Rail Road, in the west part of Chester and Middlefield, appear to me to promise fine flagstones, if explored. But hitherto they have been neglected; as they have been indeed, over the whole extent of these formations, on account of the distance of a market. Whether the rail road will open a market for this article, I am incompetent to decide.

Another point on this rail road, but east of Springfield, where it seems to me good flagstones might be procured, is in the south part of Palmer, at the locality already described in speaking of firestone, 100 rods east of Sedgwick's tavern. The rock in that hill appears as if it would split with great facility into thin and even layers. And I should not be surprised, if some one should find a quarry there a valuable speculation.

The sandstone of the valley of the Connecticut furnishes some good flagstones. Three miles above Turner's Falls in Gill, at a spot called the Horse Race, very large slabs of a gray micaceous sandstone, have been got out, that would answer admirably well. At a quarry, already described, in the southwest part of Montague, near the banks of the Connecticut, the red micaceous sandstone often forms a beautiful flagstone; and probably vast quantities could there be obtained. Another quarry on the west bank of the same river, whence a considerable quantity of flags are obtained, and carried to Northampton, is in the southeast part of that town, on the east side of Mount Tom. The quantity easily accessible here is immense: but the quality is not very good. And it is a curious fact, that many of the surfaces are almost ruined by the tracks of large animals: as may be seen on much of the flagging in Northampton. This will probably seem fabulous to those who have never seen this phenomenon: but it is most assuredly sober fact.

## 5. *Fluxes.*

It is well known that in order successfully to reduce most ores, it is necessary to mix with them other substances, that melt more easily than the ore: and these are called a flux. Besides common clay, I scarcely know of any flux in Massachusetts, that need be noticed; except that

very valuable one, limestone. And I mention that here, merely to refer to one circumstance of considerable importance, that is undoubtedly now overlooked in this state. Limestone containing a large proportion of magnesia, is far less fit for this purpose than that which is a pure carbonate of lime. But since no effort has hitherto been made to distinguish between these two kinds of stone, the proprietors of furnaces probably use them indiscrimately. The circumstance is certainly deserving of their attention, since they can without difficulty obtain in Berkshire a flux of the best kind.

### 6. *Clay in the Manufacture of Alum, Fire Bricks, &c. and as a Substitute for Fuller's Earth.*

The white clay of Martha's Vineyard, described on a preceeding page, has been somewhat extensively employed on the continent, in the manufacture of alum—of which alumina forms the basis; and for fire bricks, pipes, &c. And since that is the only deposit of this kind of clay known in New England, it can hardly be doubted but the demand for it will increase.

In my former Reports I mentioned the fact, that the common clay of the Connecticut valley had been used as a substitute for Fuller's Earth. But I was not till recently aware how extensively this substitution had been made. I am told by the Agent of the Woolen Factory in Northampton, that this substitution is made very extensively in this state and in Connecticut, and that the clay is considered even better than the Fuller's Earth for cleansing the dye-stuff from cloth. That in Northampton has been considered as rather better than in other places: and hence it is transported often quite a distance. It is also used in private families for extracting grease and oil from cloth. It is first made into a paste, and then applied and suffered to dry. It doubtless operates by its great absorbing power. When applied to the tongue it adheres very firmly. No. 2502 is a specimen from Northampton.

I learn that the clay in the north part of Worcester County is employed in the same manner: and I doubt not but the variety proper for this use may be found in many parts of the state; although that in the valley of the Connecticut appears to be rather better than any that I have met with elsewhere. Fuller's earth, which is brought from England, sells, I am told, for $10 per ton The clay can cost nothing but the transportation.

### 8. *Moulding Sand.*

To say nothing of brass, no less than 76 furnaces are in operation in Massachusetts for casting iron; and these in 1836-7 produced articles to the value of $1,205,840. Yet most of the sand for making the moulds to these articles, is obtained out of New England. It hence becomes an object of importance to discover such sand in the state. But the late period at which my attention was called to the subject, has prevented me from that thorough prosecution of it which would be desirable. And further, I find that sand of so many sorts is employed for this purpose, that I hardly know what is essential in it. It should obviously be quite infusible; and therefore must not contain much common clay; which fuses too easily on account of the oxide of iron in it. Yet silica alone will not answer, because it has not adhesiveness enough to form and preserve the mould. The white clays that are destitute of iron, when mixed with sand, form a good article for casting bells and cannon. (No. 212 *b* from New Jersey.) Hence I suspect there is a substance at Gay Head (No. 211*b*.) composed of white clay and sand, and which may be obtained there in great quantity, that would answer. This substance is quite heavy; which is another circumstance of importance: and no gas will be produced from it when heated; an occurrence that would ruin the castings. I am informed by A. A. Hayes Esq. of Roxbury, that the

substance which I have described under the name of *muck sand*, and which is often called quicksand, is employed by the brass founders in that place; and that it makes a sharp impression. The same substance is employed in Carver, as I am informed by John Savery Esq. for parting the moulds of castings and for the case of tea kettle spouts. Capt. Lemuel Drake of Easton, who has charge of extensive castings in iron, informs me, that he has obtained moulding sand, though not of the best quality, in Bridgwater, Medfield, Easton, and Foxborough. No. 166 is a specimen from the last named place; and No. 167 is from Montague: which I have placed in the collection, because it bears a resemblance to good moulding sand; although it has not been thoroughly tried. It occurs on the farm of Noah Goss, near the bridge over Connecticut river.

No. 168 is from the locality of blende and white clay in Norwich, already described; and may perhaps answer for moulding sand, as it contains no iron. The moulding sand used at the iron furnaces in Berkshire, is usually brought from Albany. It is said that a similar sand occurs in the north part of Lenox; and they bring from Lenox Mountain, decomposed mica slate to form the floor on which the melted iron is suffered to run out. I should think it strange if the decomposition of the talcose rocks on the Taconic mountain range, should not furnish some good material for moulding. In the valley of Connecticut river, also, I presume that the decomposition of the red sandstone must produce some fine sand of this description. Indeed, a fine red sand of this sort, is obtained from some town in Connecticut in that valley, which answers extremely well for castings in brass. (No. 215 *b*.) A large part of the moulding sand used for iron castings in this state, is brought from the vicinity of Albany. (No. 213 *b*.) I suspect that a similar article may be found in connection with the red and yellow ochres in the west part of New Marlborough, of which Nos. 164 *b* and 165*b* present specimens. I would also suggest, that the peculiar reddish soil, which results from the decomposition of a reddish limestone in Stockbridge, and at the Tunnel in Saddle Mountain, will probably answer for moulding sand, when it is destitute of carbonate of lime (No. 192*b*). I should think this variety might be found near the upper part of the Tunnel above mentioned.

## 9. *Ochres and Stone Paints.*

It is well known that the oxide of iron, mixed with clay or soil, forms the paints called ochre. Although very many places in our soils have an ochery appearance, yet I have not till recently met with any deposits in Massachusetts that appear to me to promise much for paints. Those, of which specimens will now be found in the State collection, seem to me worthy the attention of those who prepare colors.

The deposit which promises far more than any other that I have seen, accidentally arrested my attention, as I was passing the farm of Josiah Sheldon in the west part of New Marlborough. In several places over a hill embracing a number of acres, he has made excavations a few feet deep, and found an abundance of yellow and light red ochres, (see Nos. 164*b*, 165*b*,) which probably might yield some of the best of this sort of paints. And besides, it seems very probable, that there will be found in this field, a rich bed of the hydrate of iron, ore the hematitic iron ore, so abundant in other parts of Berkshire county.

No. 163 *b* was obtained from what is called the Jewett farm, in the north part of Rowley, on the road to Newbury. It occurs in a low spot of ground, and has been formerly used for painting a house. The specimen is of a coarser texture than those from New Marlborough: but the former excavation was nearly filled up, and I had no time to have it re-opened; so that, perhaps, this specimen does not exhibit a fair sample of this locality.

No. 161 *b* was sent me from Athol, by Alden Spooner, Esq., who says that it occurs in the north part of the town, and also in Templeton; but he gives no farther particulars.

No. 162 *b* is from Monroe, for which I am indebted to Martin Ballou Esq. He informs me that it was formerly dug to some extent and prepared for paint; but not being in much demand, the work was abandoned. It certainly appears as if it might be valuable.

No. 216 *b* is from Bedford: but I am not informed as to its extent.

At one of the beds of iron ore in Richmond in the eastern part of the town, a large quantity of yellow ochre has been thrown out; and I doubt not but it might be employed for paint. In Williamstown also, as already described, a bed of it was formerly dug and the article used. No. 217 *b* is from Harwich; where it occurs beneath peat, several inches thick. A reddish ochre is found in Boylston, mixed with clay.

The peculiar fossil paint called *apothemite*, lately found in Newbury, has already been described, when treating of the subject of soils. It has also been mentioned, that the phosphate of iron found in Hopkinton, near the mineral spring, has been used as a blue paint.

In Hatfield, is an immense quantity of the sulphate of baryta of a superior quality. Within a few years, a patent has been taken out in England, for the use of this substance as a paint, to be employed in those situations where lead paint is liable to be acted upon by moisture, acids, and other chemical agents. In such cases this barytic paint is excellent. I have been in the habit, for several years, of having various articles in the laboratory, such as the pneumatic cistern, gazometers, &c. covered with it; and it answers a good purpose, although I have prepared it not according to the patent, but simply by grinding it in a plaster mill and mixing it with oil. The greatest defect in this paint, seems to be, that it has less body than lead, although I doubt not that a remedy may be found for this difficulty. When the baryta is thoroughly pulverized, and mixed with boiled linseed oil and lampblack, it is superior to any thing I have ever seen, for labeling glass bottles, &c., in a laboratory, and indeed for any situation exposed to active chemical agents.

In this case, however, I have usually decomposed the sulphate of baryta in order to purify it, converting it first into a carbonate, and then back again into a sulphate. In whiteness it then equals the best white lead.

This mineral occurs at Southampton lead mine; also in Leverett with galena; and with copper ore in Greenfield: and in quantity sufficient to furnish a good deal of paint. But the Hatfield locality is by far the most abundant. Nor can I believe that a substance capable of such useful application, will be much longer neglected.

Other rocks, also, which have of late been used as lithic paints, abound in this state. Soapstone, of which we have such inexhaustable quantities, is considered best for this purpose, and serpentine is also employed. These are ground with whale oil; and in Connecticut, where they have been manufactured, they are sold for five dollars per hundred pounds. They answer a good purpose as a basis for common paints, especially for the roofs of houses. I should presume that the newly discovered serpentine in Lynnfield is very well adapted for this object, being unusually soft and free from foreign minerals.

### 10. *Arenaceous and Granular Quartz.*

From some unknown cause, the granular quartz in Cheshire, Berkshire county, is so much disintegrated, that it easily crumbles into a beautiful white sand. This forms a good material for glass, and has been employed for this purpose a number of years; formerly in Cheshire and Warwick, Mass., and in Utica, N. Y.; and at present in Keene, N. H. It answers well for crown and cylinder glass. The quantity is inexhaustable. It is sold at the road, one mile from the bed, at 6 1-4 cents per bushel. The sand is employed extensively in Berkshire in the process of sawing marble.

I am inclined to believe that some of the sand associated with the tertiary and diluvial formations in the State, particularly in the gneiss region, is pure enough to be employed in the manufacture of coarse kinds of glass : such for instance as is found in Pelham and Leominster. The purest and coarsest variety, however, that I have met with, forms the shores of Lock's Pond, in the northwest part of Shutesbury. This sand has been recently employed with success as a substitute for smalt, upon doors exposed to depredations from penknives and pencils.

A very beautiful sand (No. 21 *b.*) occurs at Squam, in Gloucester, of which great quantities are transported to Boston. Some of the sand on Cape Cod also is pure enough for the manufacture of glass.

In Berkshire a good deal of sand is used in the sawing of marble : and the arenaceous quartz furnishes an excellent material for this purpose. In some parts of the county, however, the transportation of good sand is expensive. Now as bowlders of granular quartz occur in almost every town, I would suggest that these be burnt in a lime kiln, until, thoroughly ignited, and then let cold water be thrown upon the pieces ; which will dispose them to fall into fine sand. It may be necessary to use a hammer : but even in this case it might be often less expensive than to transport the sand from a great distance.

## 11. *Materials for Millstones.*

In the same hill that furnishes the flagstones and fire stones in Washington, a few miles from Pittsfield, there is found a singular porous quartz, considerably resembling buhrstone, which is employed for millstones. These are prepared near the ledge and sold for 70 or 80 dollars each. I am told that they answer well, especially for the coarser kinds of grain. They are doubtless inferior to the real buhrstone ; because they are less tough. The quantity is inexhaustible. This rock, to my surprise, I find to be derived from gneiss, by the decomposition of the feldspar. But this change will be more particularly described in the scientific account of rocks that will be subsequently given.

Sometimes our citizens employ the finer and more compact varieties of granite for millstones. I have seen even a coarse *conglomerate*, or *puddingstone*, used for this purpose. And while upon this subject, I cannot but express my surprise that no attempt has been made to employ our greenstone, and other hornblende rocks, for millstones. In Great Britain, basalt has been, within a few years, used for this purpose, and found even superior to the French buhrstone ; and our greenstone is only a variety of the same rock : indeed, some of our greenstone cannot be distinguished, by the eye, from the European basalt. It is generally extremely compact and tough ; and although its preparation might require a little more labor than the buhrstone, yet it would doubtless last enough longer amply to pay for the additional labor. In the vicinity of Boston and in the Connecticut valley, as may be seen on the Map, greenstone exists in great quantities. It also occurs in small beds throughout the whole extent of the gneiss region in Worcester county ; and of a kind, which would answer the purpose even better than that of the extensive ranges above mentioned.

## 22. *Polishing Materials.*

No real emery has yet been found in Massachusetts. But in North Brookfield, a rock composed chiefly of garnet, has been used as a substitute ; as it is in Saxony and Bohemia. It is said to answer well, and is often called *red emery.* (No. 1079.)

I would suggest that probably a useful polishing powder might be prepared from the garnets that are so abundant a little distance south of the center of Warwick. (Nos. 2133. 2134. 2135.)

At Paine's quarry of limestone in West Springfield, I found a mineral which subsequent examination has convinced me is genuine tripoli or rotten stone: and it appears to be of a good quality. It occurs too in large quantities, and under circumstances similar to those in which it has been found in other parts of the world. I mean that it is associated with fetid limestone; being in fact that rock partially decomposed, and still emiting a strong fetid odor when struck. I hope that some mechanic, who has occasion to use this article, will thoroughly test that from Springfield, as I know of no other locality of any importance in the country. It does occur, however, at South Hadley falls on the West Springfield shore. But the quantity is small, and it is not there associated with limestone, but appears to be an altered shale. (Nos. 217 to 221.)

The fine siliceous matter that is sometimes mechanically deposited in the bottom of ponds, is frequently employed for scouring metals, where great delicacy is not required. The hydrate of silica, especially that most remarkable product of animalculæ, which has been described in its agricultural connection, forms an excellent polishing powder: as we might expect from the extreme fineness to which the silica must be reduced to form their skeletons.

## 13. *Alum Rock.*

It is well known that alum is often formed in rocks by their spontaneous decomposition, which may be aided by artificial means, and thus large quantities be obtained: for alum being soluble in water, is easily separated from the mass by lixiviation. Any rock that contains sulphuret of iron, potassa, and alumina, may produce it. I have found it in considerable quantity upon the gneiss of Leominster, Barre, and Ware. (Nos. 1080. 1081.) It occurs also upon mica slate in the northwest part of Conway. In all these cases it is found efflorescing upon the slate, and the rock in Conway resembles that which in England is called alum slate; that is, a variety of mica slate, which is passing into clay slate: so that if upon trial this rock be found to furnish a large quantity, the alum might profitably be manufactured. The same may be said of some localities in Berkshire County; as in Sheffield, where it is said that pounds of alum can be collected in a nearly pure state. As to the alum upon gneiss, it is found in delicate plumose masses upon that schistose variety of this rock which approximates to mica slate.

There is mixed with this alum more or less of sulphate of iron, and both minerals proceed from the decomposition of iron pyrites, and probably feldspar. This last mineral contains, as is well known, a considerable quantity of potassa; and I can imagine no other source from whence this essential ingredient of alum should be obtained. Nor will any one doubt, who has seen how thorough is often the decomposition of the gneiss that contains pyrites, that this potassa might be separated. I am not aware that alum has been heretofore found in gneiss; but since this rock does contain so much potassa, and if it can be thus separated from the feldspar, why may not our gneiss prove a very prolific source of alum? I do not know that any special efforts have been made to ascertain whether it can be procured in much quantity from the rock in Leominster: but recently I have received a specimen from Barre, and it occurs also in Ware. And I can have no doubt that any part of the gneiss range, where pyrites is decomposing, will produce it. It may be hoped that a fair trial will erelong be made to obtain this substance. It would be premature in this place, to make suggestions as to the best mode of proceeding.

Suffice it to say, that no effort should be made on a large scale, without consulting some practical chemist.

### 14. *Graphite, Plumbago, or Black Lead.*

This substance has the color of lead, leaves a trace like that metal upon paper, and bears the common name, *black lead;* but it contains no lead. It is composed of above 90 per centum of carbon, and the rest is iron and earthy matter. Hence it differs but little from some varieties of anthracite. It seems indeed to be the form in which carbon occurs in the oldest of the rocks. In Massachusetts it exists in gneiss, at the most important locality, which is in Sturbridge. It there occurs in a bed, varying in width from an inch to about two feet, and traceable along the surface, nearly one hundred rods. A number of years ago this bed was opened; and several tons of the graphite obtained. It was then abandoned; but within a few years the exploration has been recommenced, and already more than a hundred tons have been obtained. In some places the excavation is 60 or 70 feet deep. The quality of the graphite is excellent, and would not suffer by comparison with almost any in the world. (Nos. 1073 to 1075.) To what extent it may be obtained, it is not possible at present to determine. The fact, that the bed descends, almost perpendicularly, into the earth, is rather unfavorable to the miner. Yet, as it is found upon elevated ground, the mine can be conveniently drained by lateral cuts or adits to a considerable depth: and probably the exploration may be profitably continued for a long time with little machinery.

The plumbago mine above described is owned by Mr. Tudor of Boston, and yields annually about 30 tons of this mineral. It would not be strange if a drift across the strata at that place, should bring to light other beds; as they frequently occur near together with a few feet or yards of intervening rock; and as this is a valuable mineral, such an exploration might be desirable. A few miles east of this spot, on land of a Mr. Morse, quite an excavation has been made in the gneiss in pursuit of graphite: And indeed, a thin bed of it, not more than an inch or two thick, exists there: But there is a also a good deal of mica slate in thin layers, which much resembles graphite, because glazed by it; and I presume this has been mistaken for it. Such rock is quite common in the mica slate region west of Connecticut river; and indeed, real graphite occurs there; as in Cummington, Chester, Worthington, &c. I am told also, that it exists in beds of considerable thickness in the mica slate of Halifax, in Vermont; a little beyond the Massachusetts line. From the specimens sent me by Dr. James Deane, I should think this locality deserving the attention of those who would like to engage in mining operations. Plumbago also occurs in North Brookfield, Brimfield, New Marlborough, and Hinsdale.

I have already intimated that a good deal of plumbago is mixed with the anthracite of Worcester. In the south part of Millbury is a mill, at which large quantities of this semi-plumbago is ground. It is put into casks and sold in New York; but I could not learn certainly to what use it is applied.

## 15. *Glazing for Porcelain.*

The articles of pottery and porcelain made from white clay need to be covered with a glaze of some other substance: that is, with an enamel, or glass: for the clay in its pure state does not melt in common furnaces. Now feldspar and albite, whose composition is very much alike, except that the latter contains soda and the former potassa, on account of the alkalies in their composition, may be melted in a strong heat; and hence they are employed for the most delicate kinds of glazing. Common glazing, which consists of powdered gun flints, litharge and table salt, is so soft as soon to yield to the mechanical and chemical agents to which the articles are exposed; and it would be very desirable that feldspar might be employed in all cases, though, as the process for its preparation is at present conducted, it would be more expensive.

I know of no attempt to employ any of the feldspar of Massachusetts for glazing; and yet we possess in our granites, sienites, and gneiss, inexhaustable quantities; and much, no doubt, pure enough for this purpose. Can there be any doubt, for instance, that the adularia of Brimfield, Southbridge, &c. would furnish a most admirable article, since it is nothing but the very purest variety of feldspar. The best locality of albite in the state is in the north-west part of Chesterfield, on the farm of Mr. Clark: and I have understood that it was purchased not long since, by a company in New York, for the purpose of using it in the manufacture of China ware, or porcelain: but I have not learned whether they are now prosecuting the work.

Beds of feldspar and albite have been quarried in Connecticut, within a few years past, with much success. In Middletown alone, in the year 1836, seven hundred tons were dug out; six hundred of which were shipped to Liverpool.*

## 16. *Substances used by the Dentist for artificial Teeth.*

The enamel from which artificial teeth are prepared, is obtained by the fusion of pure feldspar. Now there cannot be purer feldspar than some of the adularia described in the preceeding section. I am not aware that any of it has been yet tried for this purpose; but can hardly conceive that some of the localities in the state should not yield the very best variety.

The dentist colors his enamel for teeth by rutile, or the red oxide of titanium. This also can be obtained in quantity sufficient for the purpose at several localities in the state. Perhaps the best is in Windsor, at the east part of the town, on a branch of Westfield river. Another locality of interest, recently discovered, is in the west part of Barre.

## 17. *Prospective Source of Potassa.*

While our forests yield so large a supply of fuel, from the ashes of which potassa can be obtained, we shall not need to resort to any other source for this valuable substance. But when this source fails, it is gratifying to know that we have another that is inexhaustable. Pure feldspar, contains nearly 20 per cent. of potassa; and it has recently been proposed to separate it by calcination with lime, and subsequent lixiviation. There can be no doubt but it might thus be

* Prof. Shepard's Geological Report, p. 72.

separated; and it might also be obtained from mica: which contains 16 per cent. Albite, which is usually regarded only as a variety of feldspar, treated in like manner, would yield 9 or 10 per cent. of soda. Hence we may be sure that Massachusetts can never be in want of these important alkalies, until her granite and gneiss mountains shall be destroyed.

## 18. *Prospective Source of Lithia.*

Lithia is an alkali similar to potassa and soda, which has not been known many years, and has been obtained only in small quantity, chiefly from two minerals, which in Europe are quite rare: viz. petalite and spodumene. But in Massachusetts these minerals exist in large quantity; especially the spodumene, at Goshen, Chesterfield, and Sterling. They contain from 6 to 8 per cent. of this alkali; and should it prove useful, as an alkali is very likely to do, here is a fertile source from whence it may be derived, by chemical processes, which it would be out of place and time here to describe.

## 19. *Substitute for Animal Charcoal in the Clarification of Liquids.*

The syrups of sugar and other liquids are frequently clarified by means of animal charcoal. But of late it has been found in France, that a variety of bituminous slate answers well as a substitute. And the description given of it corresponds so well to that of the bituminous slate on which are found the impressions of fish at Sunderland, that it seems desirable a trial should be made of the latter. It should be burnt, or charred, in kilns, like charcoal; and then pulverized; when it is ready for use. Pieces containing sulphuret of iron should be avoided.

## 20. *Mineral Springs.*

No mineral springs of much notoriety are found in this State, although chalybeate springs are very common, and are useful in cutaneous and some other complaints. Nearly all these springs rise in low ground containing bog ore. The Hopkinton spring is of this description, and is probbaly more resorted to than any other in the State. This contains, among other ingredients, carbonic acid and carbonate of lime and iron. The spring in Brookfield is similarly situated, and contains some magnesia and soda, as well as iron. It is a place of some resort. A mineral spring exists in Shutesbury, abounding in muriate of lime, and it is somewhat visited. Chalybeate springs exist in South Hadley, Amherst, Deerfield, and indeed, in almost every town in the State. In Mendon I was shown a mineral well, in the waters of which, chemical tests indicate muriate of lime and carbonic acid in a free state. No use was made of the water, except as a substitute for yeast.

New Lebanon is well known as the locality of a thermal spring, which attracts considerable company. It is situated only a short distance beyond the line of Massachusetts, and on the western slope of the Taconic ridge, which separates the two states. The saline ingredients are in very small quantity in this spring, and of no consequence in estimating its medicinal properties. The two circumstances that give this spring its chief interest, are its elevated temperature, and the constant escape of gas from its surface. According to Dr. Daubeny, who has recently examined this spring, its temperature is 73° F: while that of springs in the vicinity is 52°. The gas given out he finds to consist of 89.4 parts of nitrogen, and 10.6 parts of oxygen in 100 parts.

In Williamstown there exists a similar spring, issuing from the midst of diluvium, and at the western base of a mountain of quartz rock. Its temperature is not so high as that of the Lebanon spring, and it has been said that the gas which escapes is the same as atmospheric air. But this point needs re-examination by a careful analysis. This spring is not much resorted to for medicinal purposes.

I have lately discovered a spring of the same character in Mount Washington, near the south west corner of the State. It is upon the farm of a Mr. Schott, who lives in the west part of the town; and it must be at least 1000 feet above the valley of the Housatonic; and not far from the highest part of the Taconic range of mountains at that particular place. Hence its situation is very similar to that of New Lebanon: though talcose slate is the only rock in Mount Washington, whereas the Lebanon spring is near the junction of that rock with limestone. The Mount Washington spring also, must be nearly 1000 feet more elevated than that at Lebanon. At present the gas rises only over a small spot, a few inches in diameter: but I presume that were the soil removed around this spot a few inches in depth, the water and the gas would rise from a much larger area. The temperature of this spring, May 3d. 1839, was 46° F: and a spring that did not emit gas, several hundred feet lower than the one just described, and on the path to Bashapish Falls, was the same. This is on the western side of the Taconic range. But the temperature of a well six feet deep, at Mr. Schott's house, was 43°. Another spring, issuing from a hill of limestone in Egremont, the same day, was 44°. Another spring in the east part of Lee had the same temperature the day previous. But a well, 8 or 10 feet deep, at the public house on the old turnpike through Becket, had a temperature of only 38°. This is the coldest water that I ever met with in a well as deep; and I was told that it is remarkably cold through the summer. Upon the whole, I think we may fairly infer that the gas spring in Mount Washington has a temperature a little higher than others in the region; and therefore may be called a thermal spring.

I made an analysis of the gas from this spring by means of spongy plantinum and clay with hydrogen, and found it as follows, in 100 parts:

| | |
|---|---|
| Oxygen, | 4 5 |
| Nitrogen, | 95.5 |
| | 100.0 |

With lime water I could not detect any carbonic acid. I ought, however, to mention, that the gas was brought 70 or 80 miles in a bottle with some of the water, before the analysis was performed. But I could not perceive that any absorption had taken place.

## *Concluding Remarks.*

In taking a general view of the mineral resources of Massachusetts, the mind selects at once, as the most important objects, the iron and limestone of Berkshire county, and the granite of Essex, Norfolk, Bristol, and Plymouth Counties. Which of these are the most important in an economical point of

view, I shall not pretend to decide. But of three things I feel confident: First, that there exists in these portions of the State, an inexhaustible supply of these materials: secondly, that for generations to come, there will be an increasing demand for them from abroad: And thirdly, that the community in general have as yet but a very inadequate apprehension of the great pecuniary value of these vast deposits. The fact that it requires industry and ingenuity to bring these materials into a marketable state, I regard as enhancing their value: For it cannot be doubted, that an income which is the fruit of vigorous bodily and mental effort, is of twice more value than one obtained without either. Berkshire possesses the advantage of possessing the greatest variety of useful minerals; and hence is to be regarded as the chief mineral district of Massachusetts. But the granite of the eastern part of the State is directly accessible in many instances to ship navigation; while even with the increased facilities of rail roads, so propitiously commenced, the western part of the State must be of comparatively difficult access. So that upon the whole, it is not easy to say which part of the State possesses mineral resources of the greatest economical value.

I think that those who read my report on our Economical Geology, will be satisfied that there are numerous mineral deposits in the State of no small promise, yet undeveloped, or only very imperfectly made known. Who can doubt that the rich porphyries, and other ornamental rocks, that exist in such profusion and variety around Boston, will one day be found gracing the parlors of the wealthy and the tasteful? Who will believe that our numerous and extensive deposits of serpentine, will never be drawn from their hiding places and made the ornament of our public and private edifices? Nor is it an extravagant belief, that some of our gems may one day be in a measure substituted for those from foreign countries. In the central parts of the State, are immense deposits of stratified as well as unstratified rocks, that would vie with those on the coast for purposes of construction; but which now lie almost untouched; because so far from market: Yet the facilities of transportation are increasing so rapidly that we may hope that even these deposits will some day, be sought after from a distance. Then also will our numerous beds of soapstone become objects of commercial value. We have grounds also to hope much from the coal field of Norfolk and Bristol Counties; and something perhaps in this respect from the valley of the Connecticut. It is not a mere dream of fancy that inspires the hope that Hampshire County may hereafter become the chief lead yielding district of N. England; as any one, who is acquainted with its geological structure, and the numerous unopened veins of galena that show themselves at the surface, will admit; and I strongly anticipate the discovery there of tin in workable quantity. Franklin County, also, may yet supply a large district with copper: for her

surface certainly exhibits veins of that metal; and it is known that these ores are not apt to put on their best aspect at the surface. Warwick, Hawley, Bernardston and Montague, may yet set in operation numerous iron furnaces, with their magnetic ores; which, though less valuable than the iron mountains of Missouri and New York, may yet be of great importance. We hope something also from the chrome ore of Chester; as we do also from numerous other substances whose existence and uses have been pointed out in this Report.

If we recollect, also, how many mineral resources exist in the State, capable of being applied to the improvement of our soils, but which are scarcely yet known to the community, we shall indulge in still more sanguine expectations respecting the future condition of Massachusetts. The vast deposits of peat and peaty mud in our swamps, if properly applied, might convert two thirds of the State into a garden. To aid this work we have our limestones, our marls, our marly clay, our clay, our muck sand, and perhaps also our green sand; most of which substances are widely diffused, but which have as yet scarcely begun to be used.

If Massachusetts then is not recreant to her true interests, she will continue to encourage the development of her terrene and subterranean resources. For every successful application of these, will add to her wealth, her population, and her means of usefulness and happiness.

# PART II.

# SCENOGRAPHICAL GEOLOGY

## OF

## MASSACHUSETTS.

I HAVE supposed that my account of the Geology of the State would be quite imperfect, without some notice of our Scenery. Strictly speaking, indeed, scenery is not geology: and yet the contour of a country owes its peculiarities in a great measure to the character of the rocks found beneath the soil: so that the geologist, by a mere inspection of the features of the landscape, can form a very probable opinion of the nature of the rock formations. The extended plain, he will pronounce alluvial, or tertiary. The precipitous ridge or mountain, if dark colored, and unstratified, will indicate trap rocks; if light colored, granite: if the summit be rounded, and the aspect red or gray, he will suspect it to be made up of sandstone. The more extended and less precipitous mountain ranges, stretching away over many a league, correspond more nearly to the outlines of primary rocks.

But diluvial and alluvial agencies, above all other causes of Geological change, have contributed to give the surface of the earth its present outlines. Many a mountain top has been indented by vallies, and many a mountain's base has been surrounded by gravelly conical elevations, almost as if the work of art—by those diluvial agencies of which we find almost every where the traces, however difficult it may be to explain their causes. How many wild and profound gorges, cut through solid rock; how many beautiful meadows, sometimes bordered by terraces; have been the result of those aqueous operations that are now going on from day to day!

The vegetable covering of the surface depends also, very much upon the chemical nature of the rocks beneath. In the valley of Connecticut river, for example, how strikingly different is the rich and dense foliage of the alluvial meadows, from the uniform and stinted pines and shrub oaks of the diluvial plains! and how different from both, is the vegetation, when in the same valley, the marly red sandstone breaks its way to the surface! On the margin of this valley, also, where rises the precipitous trap ridge, how very peculiar is the vegetation that covers it! Compare too, the plants of that

ridge with those upon the talcose slate soil of the Taconic range of mountains. The latter is almost covered with the lofty and graceful chestnut, while the former sustains the Quercus montana or chestnut oak; the Juniperus Virginiana, or white cedar; the Acer Pennsylvanicum and montanum two dwarf species of maple, very unfrequent upon most formations.

The planes of structure in rocks, likewise, give them peculiarities of aspect. Very different, for instance, is the columnar structure of many traps, from the irregular fissures of granite and porphyry; and usually from the divisional planes of the stratified rocks. As a result of difference of structure, very unlike will be the operation of disintegrating agents; and the various forms that are thus produced, will reveal to a practiced eye at a distance the character of the rock.

From these and other considerations that might be named, we may safely assume, that the peculiarities of natural scenery depend chiefly upon geological causes; and hence I have thought it would not be a misnomer, to denominate a description of natural scenery, *Scenographical Geology*. With the modifications of natural scenery by human agency, I have little or nothing to do in this place. My chief object will be to call the attention of men of intelligence and taste, to those striking features of our scenery, that are the result chiefly of geological changes, and which produce landscapes abounding in beauty and sublimity. A few of the more frequented of these spots are well known: but very many of them have cost me much time and labor to discover; quite as much indeed, as to find out new localities of rocks and minerals: although the two objects could be conveniently prosecuted together. Some of them are yet too little known to have received a name; and in a few instances I have ventured to supply this deficiency. It will not be expected that I should describe these spots with the vividness and minuteness of the poet and the painter. My chief object has been to direct the attention of gentlemen of taste, intelligence, and leisure, to these spots; that sometime or other, their beauties and sublimities may be faithfully depicted, both on canvass and in language. In this way I hope that many of our citizens, in their excursions for relaxation and health, instead of following the beaten track to places of fashionable resort, where more is often lost in morals than is gained in health, may be induced to climb our own mountains, and traverse our own deep glens and gorges, where they will find unsophisticated nature, with the dress given her by her Creator, scarcely marred by the hand of man. In order to excite more interest in our scenery, I have succeeded in obtaining, through the liberality of several individuals,* who

* The names of the individuals to whom I am indebted for this gratuitous service, will be found upon the sketches which they have taken, except in a few cases, where a lady from New York was too diffident of her skill with the pencil to allow her name to appear.

possess a talent for drawing, quite a number of landscape sketches: and although wood cuts and even lithographic sketches can do but imperfect justice to these spots, yet I thought that even these would be preferable to naked description.

It should be remarked here, that many of the sketches were taken with a view to illustrate the geological features, as well as the scenery; and wherever it was possible to unite these two things, I have done it. This is especially the case in those sketches that contain exhibitions of diluvial phenomena. And I cannot but observe here, how superior must be the pleasure which the geologist derives from scenery, above that of the man who knows nothing of the mighty agencies by which the striking features of that scenery have been produced or modified. The latter derives all his pleasure from the simple beauty or sublimity of the spot. But along with that emotion, the mind of the former is stimulated and regaled by numerous rich and delightful associations. It is carried back through immense periods of past time, during which natural causes were operating to produce the scenery before him: and he witnesses in imagination that spot, assuming peculiar and widely diverse aspects; and sees how wisely each change was adapted to bring it into its present state. It may be too, that his mind reaches forward into futurity; and perceives other changes passing over the spot, no less interesting; and the necessary consequence of the unalterable laws which God has established.

The most striking objects in the scenery of a country, where they exist, are high and precipitous mountains; especially if extensive plains, traversed by rivers, stretch away from their bases. I shall therefore, in the first place, describe those conspicuous peaks and ridges in the State, whose summits afford wide and interesting prospects.

Massachusetts is peculiarly mountainous. But mountain scenery is not particularly interesting, if the slopes are gentle, and the outlines of the hills are much rounded. It needs the sharp towering peak, the craggy and overhanging cliff, and the roaring torrent beneath, to arrest the attention, and excite strong emotions. Such objects are numerous in this State, especially in the western part. Here we find some scenery that is truly Alpine. I begin with the highest point in the State, viz.

### *Saddle Mountain.*

We have in Massachusetts 3 rather lofty and extensive ranges of mountains, crossing the State in a north and south direction. The summit of the Taconic range, corresponds nearly with the west line of the State. The Hoosac range is separated from the Taconic by a valley several miles in width. The former occupies all the eastern part of Berkshire County, and the Western part of Franklin, Hampshire and Hampden; being from 30 to 40 miles broad, and

extending easterly to the valley of the Connecticut. East of this valley is a belt of mountainous country, embracing the eastern part of Franklin, Hampshire and Hampden Counties, and the whole of Worcester County: but no specific name has been applied as yet to this range as a whole.

Saddle Mountain does not belong, properly speaking, to any of these chains of elevated land; though generally regarded as a spur from the Hoosac range. But it is in fact an insulated eminence, which is connected at its southern extremity with the Taconic range and on the north with the Hoosac range, running diagonally between them, mostly in the town of Adams, and nearly surrounded by valleys, above which it rises 2,800 feet, and nearly 3,600 above the tide water of the ocean. It is chiefly the insulated character of this mountain, that renders it so striking an object in the scenery. Its summit is supposed to bear a resemblance to that of a saddle; and hence its unpoetic name. The highest point of the summit has a much more appropriate designation, viz. *Graylock;* from the hoary aspect which the upper part of the mountain presents in the winter months. During that season, the frost attaches itself to the trees, which, thus decorated, it needs no great stretch of imagination to regard as the gray locks of this venerable mountain. As the cold increases, the line of congelation sinks lower and lower, covering more and more of the mountain with frost work; and a contrary effect results from an increase of the temperature; so that this line is frequently rising and falling during the cold months, producing numerous fantastic changes in the aspect of the mountain.

The best route by which to ascend to the summit of Graylock, passes up the southwestern declivity of the mountain, through what is called the *Hopper;* and over that spur of the mountain denominated Bald Mountain. The ascent is so gentle that it may be gained on horseback. At present one is obliged to climb a tree, to the height of 30 or 40 feet, in order to get an unobstructed view from the summit; so that either the surrounding trees should be cleared away, or a stone or wooden structure be erected, that would overlook them. This work I am happy to find is in part completed, and efforts are making to construct even a carriage road to the summit.

I know of no place where the mind is so forcibly impressed by the idea of vastness, and even of immensity, as when the eye ranges abroad from this eminence. Towards the south you have a view, more or less interrupted by spurs from the Taconic and Hoosac ranges of mountains, of that fertile valley which crosses the whole of Berkshire County. On your right and left, you look down upon, or rather overlook, the Taconic and Hoosac mountains; which, from the valley beneath, seem of such towering height and grandeur. Beyond these mountains, on every side, you see the summits of peak beyond peak, till they are blended with the distant sky.

Upon the whole, however, I was more interested by the phenomena exhibited in that part of the mountain called the Hopper, than by a view from the summit. As the traveller descends from Graylock, let him follow out the naked summit of Bald Mountain nearly to its extremity, and then, on turning northerly, he will find before him a gulph at least a 1000 feet deep, the four sides of which seem (although it is not strictly so in fact,) to converge to a point at the bottom. The slope of these sides is so steep, that one feels dizzy on looking into the gulph. These slopes are all covered with trees of various species, among which are occasional patches of evergreens, giving to the whole a rich and captivating appearance. On the northeast side, however, may be seen the traces of several *Mountain Slides*, by which the trees and the loose soil have been swept away from the height, in some cases, of 1600 feet, and of considerable width. It is not more than ten or twelve years since one or two of these slides occurred; and the paths which they left behind, are yet quite naked of vegetation. In some instances of earlier date, we perceive the vestiges of the avalanche, only in the stinted growth, or peculiar character of the trees, that have sprung up. It is said that one of the most remarkable of these slides took place in the year 1784; and that one dwelling house was swept away by the inundation, though the inmates escaped.

If we start from the village of North Adams, we can pass up around the north end of Saddle mountain, perhaps two thirds of the way to the summit of Graylock: and proceeding to the western side of that summit, we come to a large elevated spot, improved as a pasture, and which forms the southern end of the Hopper that has been described. That deep valley here assumes a different appearance from that just described, as seen from Bald Mountain, but almost equally imposing. On turning northerly, and proceeding to the extremity of the open ground, we come to the steep margin of the mountain; and in a moment the beautiful valley and village of Williamstown, with the Colleges and Astronomical Observatory, burst like a bright vision upon the eye. On your right, the vast slope of Hoosac mountain, stretching away into Vermont; and on your left, the vast slope of the Taconic range, stretching northerly still farther; while beyond and above it, the lofty mountains in N. York west of Champlain, appear; and between the Hoosac and the Taconic, Bald mountain, a lofty eminence in the north part of Adams, rises near you in silent grandeur. In fact, I have rarely if ever experienced such a pleasing change from the emotion of beauty to that of sublimity, as at this spot. The moment one fixes his eye upon the valley of Williamstown, he cannot but exclaim "how beautiful!" But ere he is aware of it, his eye is following up and onward the vast mountain slopes above described; and in the far off horizon, he witnesses intervening ridge after ridge, peering above one another, until

they are lost in the distance; and unconsciously he finds his heart swelling with the emotions of sublimity nor can the soul of piety cease its musings here, until the tribute of reverence has been paid to that Eternal Power, who has driven asunder these everlasting mountains. This is decidedly the best view that can be obtained from Saddle Mountain.

Before one gets an accurate idea of this stupendous mountain, he must pass over it and around it in a variety of directions. I find it to consist essentially of three distinct ridges, running nearly N. 30° E. and S. 30° W. the middle one being several hundred feet the highest, and constituting Graylock. The western one more usually goes by the name of Saddle mountain. The easterly ridge is narrow and precipitous; and is separated from the middle one by a fertile valley, whose north end is nearly on a level with the valleys of North Adams and Williamstown. But it gradually ascends for several miles, until at its southern extremity, it is more than half as high as Graylock, and nearly as high as the eastern ridge of the mountain, which is thus connected at its southern extremity with the central ridge. The valley is improved throughout; and is called the Bellows, from the fact that it becomes gradually narrower towards its highest part; and when the wind is in the right direction, to blow through it southwesterly, it passes through the narrowest part with great violence. In like manner the western ridge of the mountain is separated from the central ridge by a valley, already described as the Hopper, whose bottom, at the southwestern part, is almost as deep as Williamstown valley; but in passing northeasterly, it gradually fills up until we reach the lofty cleared spot already described, which overlooks Williamstown; and there the western and central ridges unite. So that on each side of the middle ridge, we have similar valleys but sloping in opposite directions. I ought to mention that a splendid southern view is obtained from the upper part of the Bellows; though scarcely equal to that on the northwest side.

During one of my visits to this mountain, the wind was strong from the northwest, which caused it to strike the ridges nearly at right angles. I passed up from North Adams through the whole length of the valley called the Bellows; and found the wind blowing very strong directly through the valley; that is, nearly from the northeast. I then passed around the north end of the middle ridge, or Graylock, and found the direction of the wind the same as in Adams: that is, from the northwest. But when I had passed beyond the middle ridge, and came to the northern extremity of the Hopper, the wind rushed up violently from the southwest nearly:—that is, in a direction exactly opposite to its course in the Bellows. But the explanation of these curious facts is easy. The northwest wind, when it struck against the middle ridge of the mountain, which at its southern extremity curves con-

siderably towards the west, was forced northerly up the valley of the Hopper, so as to come from the southwest. But the wind that passed over and around the northern part of Graylock, striking against the eastern ridge, was turned southwesterly, through the valley of the Bellows; so as to give it a direction from the northeast. But when we rose high enough to be out of the reach of these deflecting slopes, the wind preserved its general course from the northwest. It is not probably, however, very common, that a wind would strike the mountain at precisely that angle which would produce this paradoxical phenomenon.

Fig. 8, is a distant view of Saddle mountain as seen across a beautiful sheet of water in Pittsfield, called the Pontoosuc Lake.

Fig. 8.

*Saddle Mt. across Pontoosuc Lake.*

### *Oak Hill, or Bald Mountain.*

This lofty eminence may be regarded as a continuation of Saddle mountain northeasterly; though the two are separated by a deep and narrow valley through which the road passes from Adams to Williamstown. The southern part of Bald mountain is broad and gently rounded; and being covered with woods, no interesting prospect exists from its summit. Yet from its southern slope you have a delightful view of the village of North Adams with the deep valley stretching away southerly between Hoosac and Saddle mountains: a view that well repays the labor of climbing the ridge to the height of 1000 feet. The top of the ridge must have a greater elevation than this: and in following it into Vermont, where, if I do not mistake, it unites with the Hoosac range, there are peaks still more elevated.

The Bald mountain just described must not be confounded with the southwest part of Saddle Mountain which also bears that name.

### *Hoosac Mountain.*

Hoosac mountain is a continuation southerly through Massachusetts, of the Green mountains of Vermont. Yet the name, Hoosac mountain, is not

usually applied to the range, except in the northerly part of the State. In Peru, it is called Peru mountain; and in Washington, Washington mountain. But in this work I have spoken of the whole range in Massachusetts as Hoosac mountain; for it seems undesirable to give different names to different parts of the same continuous range, unless some particular peak peer above the general surface. This mountain is for the most part very steep on the west side: but on the east, the slope is more gradual; and indeed, it may be considered as extending to the valley of Connecticut river. The main ridge, however, is near the western side; and this gradually diminishes in elevation as we go southerly.

So high and steep is this ridge, that it is no easy matter to find a proper passage for a road across it into the valleys of Berkshire. Yet several have been opened, where stages pass: One, for instance, through Florida, another through Savoy; another through Peru; another through Washington; another through Becket; another through Otis; and another through Sandisfield. And what is still more unexpected, a passage has been found for the Western Rail Road through the Pontoosuc valley. Where these roads cross the highest part of the ridge, splendid prospects are often presented; especially towards the West, where the deep valleys of Berkshire give magnificence to the towering Taconic range beyond, and the still more lofty and distant Catskills. Turning towards the east, the observer sees successive ridges of mountains with their summits now rising above, and now sinking below, one another, over a vast area.

### *Taconic Range.*

Commencing on the west of Williamstown, this lofty ridge forms almost a continuous range across the State, whose summit corresponds nearly with the line between Massachusetts and New York. On its western side, it is even more bold and precipitous than Hoosac mountain; and hence splendid prospects arrest the traveller's attention, who climbs to the summit, at almost any point. The higher the ridge, of course the wider and more imposing the prospect. But I have met with none that demand peculiar notice, till we reach the southwestern town in the State; where we have a vast mountain pile that will be described farther on. The roads over the Taconic range are much fewer than those over the Hoosac, though in several instances they pass through valleys cut through the range. The stage road from Pittsfield to Albany affords perhaps nearly as good a prospect from its highest part, as any other; though a view from an unfrequented road from Hancock to Lanesborough, is more striking. Yet as we begin to descend westerly from the summit on the Pittsfield road, the view is magnificent as well as beautiful.

## *Tom Ball.*

In proceeding southerly from Pittsfield, we are met on the right, by the northern termination of a lofty mountain ridge, rising abruptly from the plain. If we pass to the right of this bluff, we shall find a valley leading us through Richmond to West Stockbridge. If we go to the left, we shall find ourselves on the road to Lenox. But on either road we shall find in our horizon the high ridge just described; and following it onward, we shall ascertain that it is a spur from the Taconic range, which parts from it in Egremont; although at its southern part, it is so low that it might perhaps be regarded as an insulated range. In its northern part, this range is called Lenox mountain: opposite to Stockbridge, it is called Stockbridge mountain: and where it attains its highest elevation, in the north part of Alford, and south part of West Stockbridge, it is denominated Tom Ball. Though from various parts of this range we have a delightful view, as for instance when we descend the western slope on the road from Lenox to West Stockbridge; and more especially when from the mountain northwest of the village, we look southeasterly towards Lenox; yet Tom Ball, being the highest point, affords the most extensive prospect. On the north and northeast we have Pittsfield and Lenox: on the east, Stockbridge: on the south, the giant mountains of Mount Washington; and on the west, the Taconic and the distant Catskills. But in order to enjoy these and a multitude of other objects, checkering the vast area around you, it is necessary that the axe should do its office, until the summit is cleared: and it is desirable also that some morc facile ascent should be sought than the steep and entangled one over which I urged my way. Since, however, some years ago, on a fourth of July, a cannon was drawn to the summit, I infer that a better path than I found does now exist.

Near the center of West Stockbridge is an insulated eminence, several hundred feet high, whose top I have not visited; and therefore do not attempt to describe. But I doubt not the prospect must be delightful. I make the same remark in respect to Rattle Snake-Hill, in the northeast part of Stockbridge; which can hardly fail in the midst of such a valley, to furnish the lover of scenery with a rich entertainment from its summit.

## *Beartown Mountain.*

The vast pile of mountains that bears this frightful name, lies southeast of Stockbridge, south of Lee, and northeast of Great Barrington. Its elevation is nearly equal to that of the other commanding mountains of Berkshire; but its sides are much less precipitous, its top is more rounded, and

no prominent peaks shoot up above the general surface to form a resting place for the eye from the valley below, and for the feet of the wanderer, who loves to gaze on the glories of Berkshire scenery from all its mountains. Did such points exist, to give an interest to this mountain, I should not have hesitated to propose some more appropriate name than it bears.

### *Alum Hill, South Mountain and East Mountain.*

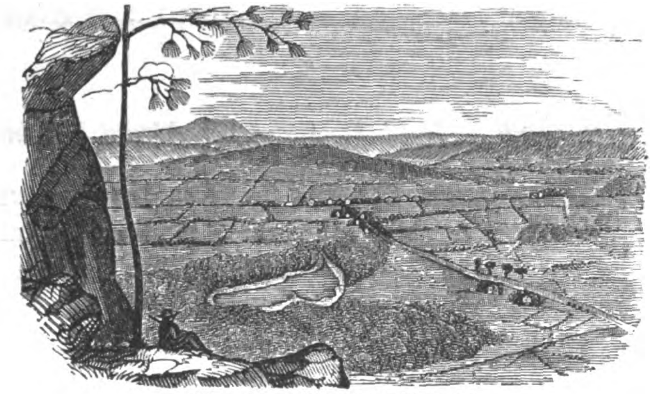
The range of hills thus denominated, may be considered perhaps as a continuation of the Beartown mountains; though in a good measure separated from them by a narrow valley. This range is also more easterly than the Beartown *pile;* for one can hardly say that the latter has any particular *range.* The former extends along the east side of the Housatonic from Great Barrington to Sheffield, and rises in some places to the height of 1600 feet above the valley. Its northern part in Great Barrington, is called Alum Hill; in the south part of that town it is sometimes called South Mountain; and its southern part in Sheffield, goes by the name of East or Northeast Mountain. Being precipitous on the west side, many points of its top furnish fine prospects; and there is another object of scenographical interest here, which I shall describe in another place. The valley of the Housatonic, with its beautiful villages, and the lofty hills of Mount Washington, are the principal objects that arrest the attention from this ridge.

### *Monument Mountain.*

A little north east of the village of Great Barrington, the ridge of hills above described comes to an abrupt termination. But on proceeding northerly, it soon re-appears; and in the north part of the town, and in the south part of Stockbridge, forms the imposing ridge known by the name of Monument Mountain, from the fact that a pile of stones is found at its southern extremity, supposed to be the work of the aboriginees, to celebrate some event in their history. It does not rise more than 500 feet above the plain, and 1250 above tide water; but its eastern side is an almost perpendicular wall of white granular quartz; and shooting out boldly as it does into the heart of a beautiful country, the prospect from its summit is delightful. Perhaps the view northerly is most striking. There the sunny village of Stockbridge, and that of Curtisville in the same town, are in distinct view; with at least two ponds of water, and mountain beyond mountain forming the distant outline. Among the latter, Saddle mountain is distinctly visible; and even some part of the Green mountains. On the east, lie the Beartown mountains; on the south, the delightful village of Great Barrington, with Alum Hill on the left, and the grand outlines of Mount Washington on the right richly fill up that quarter; while on the west, the blue Catskill are

seen over a depression in the Taconic range. Fig. 9, will convey some idea of the northerly prospect from this spot.

Fig 9



*View from Monument Mountain.*

At the eastern base of this mountain the principal road from Stockbridge to Great Barrington passes; and it is possible to climb to the top directly from this road. But the usual route passes around the south end of the mountain, and ascends upon its backside. In going up the eastern side, we must clamber over a vast quantity of huge blocks, which frost and time have detached from the impending precipice above. In several places frowning masses are still left projecting from the cliff, more than 200 feet above the base, still holding on to the parent rock with apparent firmness. And it is an interesting trial of the nerves, to creep to the edge of these jutting masses, and to look down upon the fragments some hundreds of feet below. This is a feat which not every man is able to perform. For he sees fissures in every direction around the projecting masses; and there is evidence in the numberless fragments beneath, that just such masses have fallen in a thousand instances; and the thought cannot but occur, that perhaps the one on which he is now venturing himself, may be just in that state when it needs only his additional weight to precipitate it to the yawning bottom. He, however, who loves the exhilaration of looking over such a precipice, will try to dismiss this imagination and will not be satisfied until the feat is done. Yet even when the fear of falling is overcome, the head begins to grow dizzy; and the man starts back with the exclamation,

"How dreadful
And dizzy 'tis to cast one's eyes so low,
———————I'll look no more,
Lest my brain turn."———

Near the highest part of this cliff, a pointed mass of the rock, only a few feet in diameter, has been parted at the top from the mountain: but its base not giving way, it now stands insulated and from 50 to 100 feet high. It

goes by the name of Pulpit Rock: But I should judge that no one could climb to its top. As one ascends along the edge of the precipice, a few rods south of this rock, it looms up so finely against the northern horizon, and the landscape moreover in that direction is so fine, that I have given a sketch of it in Plate I.

*Mount Everett, (Ball or Bald Mountain,) in Mount Washington.*

As the traveller passes down the valley of the Housatonic through Sheffield, he cannot but observe a few miles to the right, a mountain of imposing form and height. This lies in the township of Mount Washington, or rather in connection with the Taconic mountain, it constitutes the township: the whole of it being in fact nothing but a mountain. Hence it is that the mountain in its eastern part is often confounded with the township. Within the town itself, I have heard the name of Ball, or Bald Mountain, applied to this eminence: but in the neighboring towns, this name I believe is rarely given. And were this its common designation, I cannot but believe that all the inhabitants of that portion of the State would gladly substitute some other good name. For I have already described two mountains by the name of Ball or Bald Mountain, in the county; and *Tom Ball* makes a third. And besides, who is willing that so splendid a mountain as this, should bear so untasteful a name. In many respects this mountain is the finest in Massachusetts. Its height is rather more than 2600 feet. It lies, moreover, in a portion of the State interesting not only by the intelligence and refinement of its inhabitants, but by historical associations. It deserves, therefore, a name that will connect it with the literature and history of Massachusetts. Such a name I trust all without distinction of political party, (from which I desire to stand entirely aloof,) will acknowledge that of our present Chief Magistrate to be. I cannot, therefore, but hope that the proposal which I make to denominate this eminence *Mount Everett*, may meet with the approbation and support of my fellow citizens.

It is surprising how little is known of Mount Washington, and especially of its scenery, in other parts of Massachusetts. I doubt whether nine out of ten of our intelligent citizens, beyond Berkshire County, are not ignorant of the existence of such a township within our limits. And even in the vicinity, very few have ever heard of scenery in that place, which would almost repay a lover of nature for a voyage across the Atlantic. I shall confine myself in this place to a general description of the township, with its principal mountains.

The best and almost the only way of getting into Mount Washington from Massachusetts, is through Egremont. Passing up along a vast uncultivated

slope to the height of nearly 2000 feet, you at length reach the broad valley where the few scattered inhabitants of the town reside:

> "A lowly vale, and yet uplifted high
> Among the mountains; even as if the spot
> Had been from eldest time by wish of theirs,
> So placed, to be shut out from all the world."

The western side of this valley is formed by the Taconic ridge, which, towards the Connecticut line, must rise nearly 1000 feet above the valley: and there it takes the name of Alender Mountain. Of course the prospect from its top must be very extensive in the States of New York, Connecticut, and Massachusetts. But there is no particular part of the mountain that calls for specific description.

On the east side of this valley, rises Mount Everett. Its central part is a somewhat conical, almost naked eminence; except that numerous yellow pines, two or three feet high, and whortleberry bushes, have fixed themselves wherever the crevices of the roek afford sufficient soil. Hence the view from the summit is entirely unobstructed. And what a view!

> "In depth, in height, in circuit, how serene
> The spectacle, how pure!—Of Nature's works
> In earth and air,———
> A revelation infinite it seems."

You feel yourself to be standing above every thing around you; and feel the proud consciousness of literally looking down upon all terrestrial scenes. Before you on the east, the valley through which the Housatonic meanders, stretches far northward in Massachusetts, and Southward into Connecticut; sprinkled over with copse and glebe, with small sheets of water, and beautiful villages. To the southeast especially, a large sheet of water appears, I believe in Canaan, of surpassing beauty. In the southwest, the gigantic Alender, Riga, and other mountains more remote, seem to bear the blue heavens on their heads in calm majesty; while stretching across the far distant west, the Catskills hang like the curtains of the sky. O what a glorious display of mountains all around you! and how does one in such a spot turn round and round, and drink in new glories, and feel his heart swelling more and more with emotions of sublimity, until the tired optic nerve shrinks from its office.

> "Ah that such beauty, varying in the light
> Of living nature, cannot be portrayed
> By words, nor by the pencil's silent skill,
> But is the property of him alone
> Who hath beheld it, noted it with care
> And in his mind recorded it with love."

This certainly is the grandest prospect in Massachusetts: though others are more beautiful. And the first hour that one spends in such a spot is among the richest treasures that memory lays up in her storehouse.

The evidence which the geologist perceives upon this mountain, and indeed upon nearly every other in Berkshire, that has been described, of former mighty revolutions, greatly enhances his pleasure. The description of these, however, is more appropriate to a subsequent part of my report. Suffice it to say, that he finds decided proof here, that these mountains at no very remote period, have been covered and swept over by powerful currents of water, that have in a great measure brought them into their present form: and that at a period still more remote, they have been lifted up and tossed over in a surprising manner.

### *Hilly Region between the top of Hoosac Mountain and Connecticut River.*

The valleys in this broad tract, usually run nearly north and south; intersected however, by others crossing these in various directions. The great depth of these valleys, and the irregularity of the intervening hills, produce a multitude of most interesting prospects; which are unnoticed by the inhabi tants themselves, only because they are so common. Very different will be the feelings of one who goes thither from long confinement in the crowded city, or from the monotonous scenery of a level country.

It is extremly exhilarating to the spirits of the tasteful traveller, as he traverses these regions, especially in summer, to find such a constant variety of landscape attending every change of place. For every new hill that he climbs, he is rewarded by the discovery of some new grouping of the distant mountains; some new peak or ridge rising fantastically in the horizon; some new village crowning the distant hill with its neat white houses and church spire; or some hitherto unseen valley opens before him, through which tumbles the mountain torrent; while the vast slopes of the valley present so much diversity, softness, and richness of foliage, as to form a lovely resting place for the eye.

In such mountainous regions it was natural for the first settlers to select elevated situations for a residence. Hence in many instances the tops of these ridges are crowned with many pleasant villages. Among those which are thus situated and afford the most romantic prospects, may be named Blanford, Granville, Tolland, Chester, Middlefield, Peru, Windsor, Chesterfield, Goshen, Cummington, Plainfield, Ashfield, Hawley, Shelburne, Rowe, Heath, and Leyden. To one accustomed to reside in a valley, it is interesting to witness in one of these places, the setting, but more particularly the rising of the sun: when very probably he will see a dense fog resting upon the valleys below, and shutting out the sun, while it shines in all its glory upon the hills around the observer. Sometimes this phenomenon occurs in winter.

" 'Tis morn: with gold the verdant mountain glows;
More high the snowy peaks with hues of rose.
Far stretched beneath the many tinted hills
A mighty waste of mist the valley fills;
A solemn sea! whose vales and mountains round
Stand motionless to awful silence bound:
Like leaning masts of stranded ships appear
The pines that near the coast their summit rear.
Of cabins, woods, and lawns, a pleasant shore,
Bound calm and clear the chaos still and hoar.
Loud through that midway gulf ascending, sound
Unumbered streams, with hollow roar profound;
Mount through the nearer mist, the chant of birds,
And talking voices and the low of herds;
The bark of dogs, the drowsy tinkling bell,
And wild wood mountain lutes of saddest swell."

In the elevated region east of Connecticut river, a still larger number of villages have been built upon heights commanding wide horizons: and some of these, being in a superior style of architecture, are most attractive objects to the distant traveller. What for instance can be á finer object, than the beautiful village of Leicester, seen at a distance of six or eight miles! or than Shrewsbury, Grafton, Charlton or Rutland! Similarly situated are Dudley, Sutton, Mendon, Hopkinton, Spencer, New Braintree, Hardwick, Barre, Petersham, Shutesbury, New Salem, Templeton, Winchendon, Princeton, Westford, Andover, &c. The extent and beauty of the summer prospect from the last mentioned place have long been the admiration of the traveller.

### *Mount Holyoke.*

We come now to the valley of the Connecticut, where is some of the boldest and most beautiful scenery in the State. Mount Holyoke in Hadley claims the first notice; not on account of its superior altitude, for it is only 830 feet above the Connecticut at its base, and about 900 above Boston Harbor: but on account of its peculiar position in respect to interesting objects around. It is a part of a mountain ridge of greenstone, commencing with West Rock, near New Haven, and proceeding northerly, interrupted only by occasional valleys, across the whole of Connecticut, until it enters Massachusetts between West Springfield and Southwick, and proceeds along the west line of the first named place, and along the east line of Westfield, Easthampton, and Northampton, to the banks of the Connecticut. Until it reaches Easthampton, its elevation is small. But there it suddenly mounts up to the height of nearly a thousand feet, and forms Mount Tom. The ridge crosses the Connecticut, in a northeast direction, and curving still more to the east, passes along the dividing line of Amherst and South Hadley, until it terminates ten miles from the river in the northwest part of Belchertown. All that part of the ridge east of the river, is called Holyoke: though the

prospect house is erected near its southwestern extremity, opposite Northampton, and near the Connecticut. And that is undoubtedly the most commanding spot on the mountain, though several distinct summits, that have as yet received no uniform name, afford delightful prospects. It is not generally known, indeed, how a slight change of situation upon a mountain, will often put an almost entirely new aspect upon the surrounding scenery: Or how rather,

> "Change of place
> From kindred features diversely combin'd
> Produces change of beauty ever new."

A knowledge of this fact, might often give a tenfold duration to the pleasure of the observer. The man who means to feast to the full upon mountain scenery, should be accoutred in such a manner that he can turn aside from the beaten track, urge his way through the tangled thicket, and climb the craggy cliff. There is a peculiar pleasure, which such a man only can experience, in feeling that he has reached a point perhaps never trodden by human foot, and is the first of the rational creation that ever feasted on the landscape before him.

In the view from Holyoke we have the grand and the beautiful united; the latter, however, greatly predominating. The observer finds himself lifted up nearly a thousand feet from the midst of a plain, which, northerly and southerly, is of great extent; and so comparatively narrow is the naked rock on which he stands, that he wonders why the winds and storms of centuries have not broken it down. He soon, however, forgets the mountain beneath him, in the absorbing beauties before him. For it is not a barren unenlivened plain on which his eye rests: but a rich alluvial valley, geometrically diversified in the summer with grass, corn, grain, and whatever else laborious industry has there reared. On the west, and a little elevated above the general level, the eye turns with delight to the populous village of Northampton; exhibiting in its public edifices, and private dwellings an unusual degree of neatness and elegance. A little more to the right, the quiet and substantial villages of Hadley and Hatfield, and still farther east and more distant, Amherst with its College, Gymnasium, and Academy, on a commanding eminence, form pleasant resting places for the eye. But the object that perhaps most of all arrests the attention of a man of taste, is the Connecticut, winding its way majestically, yet most beautifully, through the meadows of Hatfield, Hadley, and Northampton; and directly in front of Holyoke, as if it loved to linger in so tranquil a spot, it sweeps around in a graceful curve of three miles extent, without advancing in its oceanward course a hundred rods.* Then it passes directly through the deep opening between Holyoke

* Alas! as if indignant at this personification, the river during the floods of last spring (1840,) has cut across the neck of this peninsula! It still continues, however, to pass around the curve, as well as through the new channel: and for several years we may hope that the beauty of the spot will not be at all impaired.

and Tom, which its own waters, or more probably, other agencies have excavated in early times. Below this point, the Connecticut is in full view, like a serpentine mirror, for nearly twenty miles. And through a deception, explicable by the laws of perspective, there seems to be a gradual ascent of the river, the whole distance, till at its vanishing place it seems elevated nearly to a level with the eye: just as the parallel sides of a long avenue seem to approach nearer until they meet.

The valley on the south of Holyoke is not as interesting as that on the west and north; chiefly because the land is less fertile. The village of South Hadley, with Mount Holyoke Female Seminary, is indeed a pleasing object. But Springfield, one of the loveliest spots in America, is too far removed for an exhibition of its beauty. Other places south of Springfield are indistinctly visible along the banks of the Connecticut: and even the spires of some of the churches in Hartford, may be seen in good weather, just rising above the trees. Still farther south in that direction, may be seen the abrupt greenstone bluffs midway between Hartford and New Haven; and looking with a telescope between these, other low hills may be indistinctly seen, which may be the trap ridge encircling New Haven.

Facing the southwest, the observer has before him on the opposite side of the river, the ridge called Mount Tom, rising one or two hundred feet higher than Holyoke, and dividing the valley of the Connecticut longitudinally. The western branch of this valley is bounded on the west by the eastern slope of the Hoosac range of mountains; which, as seen from Holyoke, rises ridge above ridge for more than twenty miles, chequered with cultivated fields and forests, and not unfrequently enlivened by villages and church spires. In the northwest Graylock may be seen peering above the Hoosac; and still farther north, several of the lofty peaks of the Green Mountains (wnich are merely a continuation of the Hoosac,) shoot up beyond the region of the clouds, in imposing grandeur. A little to the south of west, the beautiful outline of Mount Everett is often visible. Nearer at hand and in the valley of the Connecticut, the insulated Sugar Loaves and Toby present their fantastic outlines: while far in the northeast, stands in insulated grandeur the cloud-capt Monadnoc.

Probably under favorable circumstanaes, not less than 30 churches, in as many towns are visible from Holyoke. The north and south diameter of the field of vision there, can scarcely be less than 150 miles.

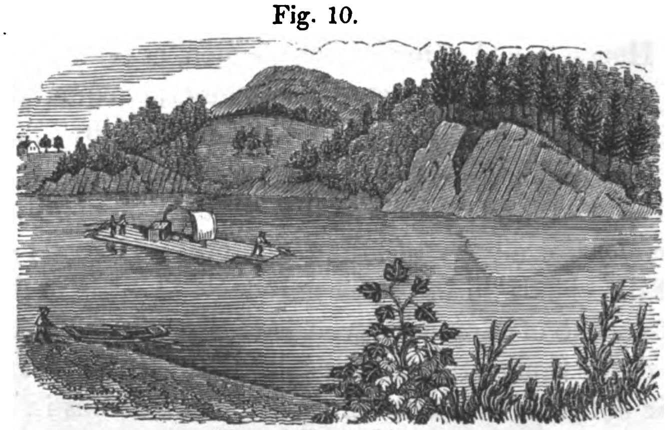
Plate 2 is a southwestern view from the top of Holyoke showing Mt. Tom. copied from a sketch by H. T. Bartlett.

*Titan's Pier.*

Standing upon Holyoke and facing the south, one has directly before him, and as it were under his feet, the deep gorge between Holyoke and Tom, through which Connecticut river passes. Following the western side of the

mountain, as it rapidly descends to the river, we find it terminating with a naked rock extending several rods into the river, and nearly perpendicular on the side next to the water, from 20 to 100 feet high. A considerable part of this naked rock exhibits a columnar structure: not in general very perfect yet sufficiently regular to require little aid from the imagination, to be regarded as artificial; though obviously demanding giant strength for its construction. I have said that the columnar structure was not in general very perfect. But if one can work his way along the western face of this precipice at low water, he will find, near where the rock passes under the river, the tops of numerous columns of great regularity; their upper portions having been removed by the force of the stream, which for so many centuries has been battering this cliff with logs and ice. By referring to the next part of my Report, a more definite idea can be obtained of these columns. But from what I have now said, every intelligent man will perceive that they are very similar to those on the coast of Ireland, which form *Fingal's Cave* and the *Giant's Causeway.* The nature of the rock too, is essentially the same in all these places. Why then may I not be permitted to denominate this rock, *Titan's Pier?* At least, may I not hope by this description to attract the attention of visitors to Holyoke, to this spot? Hitherto it has been passed unnoticed. Fig. 10, is a view of Titan's Pier, with Holyoke in the back ground, as seen from the opposite side of the river.

Fig. 10.



*View of Titan's Pier.*

### *Titan's Piazzi.*

Less than half a mile south of the point where the road that leads to the Prospect House on Holyoke strikes against the steep part of the mountain, and turn northerly, may be found an interesting and unique example of greenstone columns. After climbing up some 50 feet over the loose angular fragments, that have fallen from these columns, by the action of frost and gravity, and which form a talus whose slope is nearly 40,° the observer finds himself standing underneath a projecting mass of columns, whose lower ex-

tremities have worn away and fallen: and from the manner in which the fragments have cleaved off, the ends of the columns over head, have assumed the form of a hemisphere, more commonly that of a paraboloid, and sometimes they are even lenticular.* At least three rows of these columns, each of which is not less than two and sometimes three feet in diameter, thus project forward from the cliff, over the observer's head. It seems as if you were standing beneath so many large hexagonal kettles, set closely together. Yet when you think how feebly the columns hold on upon one another, and see around you the evidence that thousands and thousands have fallen, and think how instantly even one of them falling upon a man would annihilate him, you cannot feel perfectly easy, while standing beneath such a Piazza, interesting though it be. Fig. 12 is an attempt to exhibit this spot: though from its situation, a sketch must be necessarily very imperfect. If the spot already described as Titan's Pier, deserve that name, with still more propriety may we denominate this place, *Titan's Piazza.*

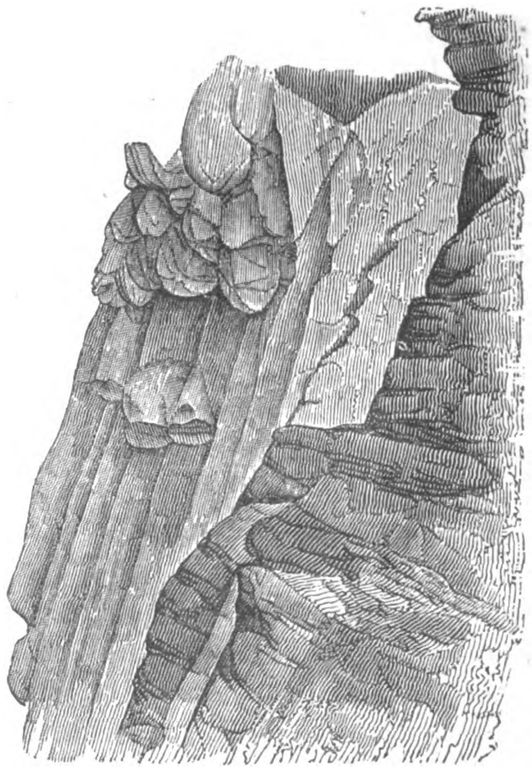
Fig. 12.

*Titan's Piazza: Mt. Holyoke.*

* A few years since, in company with a very intelligent gentleman from Europe, I visited this spot, and the large yellow hornet had fixed his enormous nest among these columns, whose lower extremity very much resembled that of the columns; while its size was nearly a foot. This gentleman, never having seen, one of these nests, seriously inquired whether the hornets had not constructed it in mimicry of the columns!

By passing a few rods northerly from the spot above exhibited, we come to another example of projecting columns, or rather to the other end of the Piazza; and though essentially like the southern part, yet being much more elevated, and the overhanging extremities more perfect in their form, it makes an agreeable variety for the observer. Fig. 13, is a sketch taken at this spot.

Fig. 13.



*Titan's Piazza.*

While the summit of Holyoke attracts crowds of visiters, but very few I have reason to believe go to this Piazza: yet I have never known any one visit it who was not highly gratified. Indeed, how can one, who has any taste for Nature in her most curious aspects, remain uninterested as he stands there

> "Gazing, and takes into his mind and heart,
> With undistracted reverence, the effect
> Of those proportions where the Almighty hand
> That made the worlds, the Sovereign Architect,
> Has deigned to work as if by human art."

### *Mount Tom.*

As this is higher than Holyoke, and insulated in the same great valley, the view from its summit cannot but be commanding; yet most of the interesting group of objects around the base of the former, is wanting around the

the latter. Hence Tom is not much frequented; while during the summer months, Holyoke is a place of great resort.

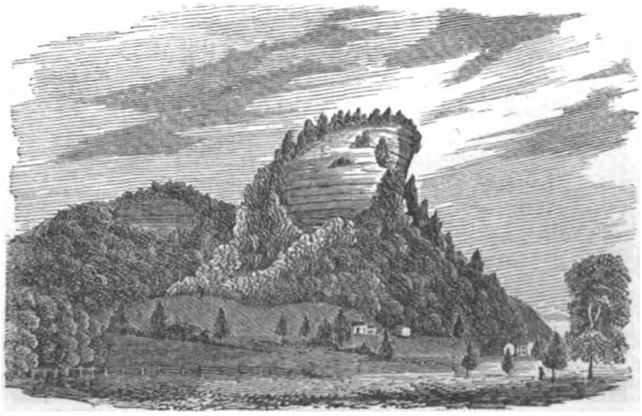
I obtained from this mountain one summer morning, a striking view, while yet the whole valley of the Connecticut was enveloped in fog, and Tom with a few other elevated peaks connected with the greenstone range, alone rose above the vapor. The sun shining brightly and the wind gently blowing, gave to this fog a strong resemblance to an agitated ocean. To the north and south it seemed illimitable; but on the east and the west, the high mountain ranges that form the boundaries of the valley of the Connecticut, constituted its shores. I could not but feel transported back to that remote period, when this great valley was enveloped in like manner by water, and Holyoke and Tom formed only low and picturesque islands upon its surface.

### *Sugar Loaf Mountain.*

No object in the valley of the Connecticut, is more picturesque than this conical peak of red sandstone, which rises almost perpendicularly 500 feet above the plain, on the bank of the Connecticut, in the south part of Deerfield. As the traveler approaches this hill from the south, it seems as if it summit was inaccessible. But it can be attained without difficulty on foot, and affords a delightful view on almost every side. The Connecticut and the peaceful village of Sunderland on its bank, appear so near, that one imagines he might almost reach them by a single leap.

This mountain overlooks the site of some of the most sanguinary scenes that occurred during the early settlement of this region. A little south of the mountain the Indians were defeated in 1675 by Captains Lathrop and Beers: and one mile northwest, where the village of Bloody Brook now stands, (which derived its name from the circumstance,) in the same year, Captain Lathrop was drawn into an ambuscade, with a company of "eighty young men, the very flower of Essex County," who were nearly all destroyed.

Fig. 14.



*Northern View of Sugar Loaf.*

### *Deerfield Mountain.*

A sandstone ridge commences at Sugar Loaf, and runs northerly through Deerfield and Greenfield, into Gill, increasing in height as far as the village of Deerfield, where it is 700 feet above the plain on which that village stands. Standing near this point, on the western edge of the mountain, a most enchanting panorama opens to view. The alluvial plain on which Deerfield, stands is sunk nearly 100 feet below the general level of the Connecticut valley; and at the southwest part of this basin, Deerfield river is seen emerging from the mountains, and winding in the most graceful curves along its whole western border. Still more beneath the eye is the village, remarkable for regularity, and for the number and size of the trees along the principal street. The meadows, a little beyond, are one of the most verdant and fertile spots in New England. Upon the whole, this view is one of the most perfect pictures of rural peace and happiness that can be imagined.

A few miles north of Deerfield and in the same valley, but on higher ground, can be seen the lovely village of Greenfield. As we approach this place from the south, the view is really one of the most enchanting in the state.

> " How gay the habitations that bedeck
> This fertile valley! Not a house but seems
> To give assurance of content within;
> Enbosomed happiness and placid love;
> As if the sunshine of the day were met
> By answering brightness in the hearts of all,
> Who walk this favored ground."

### *Mount Toby.*

This mountain of sandstone lies in the north part of Sunderland, and west part of Leverett, and is separated from Sugar Loaf and Deerfield Mountain by Connecticut river. A valley also separates it from the primitive region on the east; so that it stands there, an immense pile of irregular shape, indented by several valleys and mostly covered by forests. On various parts of the mountain interesting views may be obtained: but at the southern extremity of the highest ridge, a finer view of the valley of the Connecticut is obtained than can be got from any other eminence. Elevated above the river nearly 1000 feet, and but a little distance from it, its meanderings lie directly before you: and the villages that line its banks—Sunderland, Hadley, Hatfield, Northampton, and Amherst, appear like so many sparkling gems in its crown. It is a pity that as yet one is obliged to climb a tree in order to enjoy this fine prospect. Indeed, the spot is unknown to most:

but were the trees cleared away, and a convenient path opened, I am sure it must become a place of no little resort.

It has frequently been stated, and that too by very respectable authority, that the ridges forming East and West Rock, Holyoke, Toby, &c., are a part of the broad ranges, which, commencing at Long Island Sound, rise gradually towards the north into the Hoosac and Green Mountains on the west side of Connecticut river, and into Monadnoc and the White Mountains on the east side. But a slight knowledge of the geological character of these mountains, is sufficient to show, that the trap and conglomerate ridges along the Connecticut, differ, *toto cœlo*, from the primary ranges on either side. And a slight examination of the topography of these mountains, shows that the former are uniformly separated by deep valleys from the latter, and have no geographical connection except proximity.

What a pity it is, that so many of the most interesting mountains and hills in Massachusetts have got attached to them such uncouth and vulgar names! How must the poets lines

> ————scramble up and down
> On disproportioned legs, like Kangaroo,

if such words as Saddle Mountain, Rattle Snake Hill, Bear Town Mountain, Mount Tom, Mount Toby, Sugar Loaf, Blue Mountain, and Deerfield Mountain, be introduced. Holyoke, Taconic, Hoosac and Wachusett, are more tolerable; though most of them have an Indian origin. It would have been fortunate, if our forefathers had not attempted in general to supersede the aboriginal designations. For what mountain can ever become an object of much regard and attachment, if its beauties and sublimities cannot be introduced into a nation's poetry, without producing the most ridiculous associations! Fortunately there are some summits in the State yet unnamed. It is to be hoped that men of taste, will see to it, that neither Tom, nor Toby, nor Bears, nor Rattle Snakes, nor Sugar Loaves, shall be *Saddled* upon them.

### *Mount Warner.*

I mention this hill of only 200 or 300 feet in height, on account of the rich view which is seen from its top, of that portion of the valley of the Connecticut just described. It lies in the north part of Hadley, not more than a half a mile from the river, and only two miles from Amherst; and its top can be easily reached by a carriage. A visit to it can, therefore, be performed by the invalid; and will form no mean substitute for an excursion to Holyoke or Toby.

### *Wachusett.*

This mountain is in Princeton, whose general elevation, above the ocean, is 1100 feet: and the mountain lifts its conical head 1900 feet higher, so as to be 3000 feet above Massachusetts Bay. The ascent on foot is not difficult. From the summit, which is little more than naked rock, the eye takes in a vast extent of country on every side. On the east and south, the distant hills are comparatively low, and seem to possess an even outline. On the west and northwest, mountain ridges and peaks succeed one another, becoming more and more faint, until the distant Hoosac and Green Mountains fade away into the blue heavens. Several neat villages around the base of this mountain, with numerous ponds of considerable extent, give an interesting variety and liveliness to the picture. Probably more of Massachusetts may be seen from this mountain than from any other in the State. It attracts numerous visitors, and a small square wooden tower has been erected on the top: but it is now in ruins.

One of the most impressive circumstances in such a spot, if the air be clear and the winds at rest, is the serene quiet which there reigns: a state of nature that greatly heightens the sublimity of the scene.

"How still! no irreligious sound or sight
Rouses the soul from her severe delight,
An idle voice the sabbath region fills
Of Deep that calls to Deep across the hills."

### *Mount Grace.*

Along the northern part of the state, between Connecticut and Merrimack rivers, are numerous high hills which afford prospects from their summits more or less interesting, But the most striking elevation is Mount Grace, a little northwest of the center of Warwick. Rising in an abrupt manner several hundred feet above the general level, (which is itself a very high one,) it affords a wide range of vision, embracing many objects of interest. Among these are Wachusett, just described, and still nearer, Monadnoc, within the limits of New Hampshire.

### *Blue Hills.*

This is the highest and most conspicuous range of hills in the vicinity of Boston. It is most elevated at its western extremity, in the southwest part of Milton, where it rises 710 feet above the ocean. A little to the southeast, and just within the limits of Quincy, the summit is elevated 680 feet. Still

farther east, it is 570 feet. Northeast a little from this peak, is another 530 feet high. The Monument Quarry in the northeast part of these hills, is 390 feet high; and Pine Hill, to the southeast of this quarry, is 235 feet high. All these summits command extensive and most interesting prospects. And there are some circumstances that impart to these landscapes peculiar interest. One is the proximity of these hills to Boston; whose numerous edifices, masts, spires, and towers, and, nobly peering above the rest, the dome of the State House, present before the observer, a most forcible example of human skill and industry, vieing with, and almost eclipsing nature. And the high state of cultivation exhibited in the vicinity of Boston, with the numerous elegant mansions of private gentlemen, crowning almost every hill, and imparting an air of freshness and animation to the valley and the plain, testify how much taste and wealth can do in giving new charms to the face of nature.

From these hills the observer has also a fine view of Boston Harbor; and this is another circumstance of peculiar interest. For to look out upon the ocean is always an imposing sight; but when that ocean is studded with islands, most picturesque in shape and position, and the frequent sail is seen gliding among them, he must be insensible indeed, whose soul does not kindle at the scene, and linger upon it with delight.

On Monument Hill, is opened perhaps the largest of the quarries of Quincy granite; and from thence a rail road runs directly to Neponset river: and this is another circumstance of peculiar interest to the visitor of these hills. Let him ascend the granite tower, which the proprietors of the quarry have erected on its site, and he will have before him, not merely the rich variety of natural and artificial objects above described, but this railway, also, stretching away for miles in a right line towards the river, with here and there the cars going and returning. Such conveyances, however, have ceased to be a novelty in Massachusetts.

Many other hills of moderate altitude around Boston, particularly on the south of the city, might be mentioned as worthy of a visit for the prospects presented from their summits. The heights of the following are given on Hale's beautiful "Map of Boston and its vicinity."

| | | |
|---|---|---|
| In Quincy, near the Common, | | 210 feet. |
| do. | One mile north, | 175 |
| do. | A half mile farther north, | 107 |
| do. | A little N. W. of Hon. J. Quincy's seat, | 40 |
| do. | Great Hill, near the eastern extremity of the town, | 94 |
| do. | Squantum, | 99 |
| In Braintree, near the east line, | | 205 |
| In Weymouth, near the west line, | | 210 |

| | | |
|---|---|---|
| In Plymouth, Near Town River Bay, | - - | 134 feet. |
| In Hingham, N. W. part of the town, | - - | 112 |
| do. On Crown Point, | - - - | 102 |
| do. A little N. W. of Mr. Brook's M. House, | - | 107 |
| In Hingham, a little south of Mr. Brook's M. House, | - | 75 |
| do. Near the east line of the town, | - - | 230 |
| In Cohasset, near the west line of the town, | - - | 215 |
| do. A mile south of Nantasket Beach, | - | 175 |
| do. N. E. part of the town, close to the shore, | - | 110 |
| In Milton, at the Academy, | - - - - | 208 |
| do. One mile south of this place, | - - | 226 |
| do. A mile west of the last, | - - - | 217 |
| do. N. W. part of the town, | - - - | 216 |
| In Dedham, at Mr. White's M. House, | - - | 405 |
| In Dover, Pine Hill, south part, | - - - | 400 |
| In Waltham, Prospect Hill, | - - - - | 470 |
| do. Bear Hill, | - - - - | 510 |
| do. Near the N. E. line of the town, | - - | 570 |
| In Lincoln, Dr. Stearns' M. House, | - - - | 470 |
| do. Mount Tabor, | - - - - | 370 |
| In West Cambridge, near the S. W. line of the town, | - | 320 |
| In Watertown, N. W. corner, | - - - - | 310 |
| In Charlestown, Prospect Hill, | - - - | 120 |
| do Winter Hill, | - - - - | 120 |
| In Chelsea, Pulling Point, | - - - - | 84 |
| In Lynn, near Phillip's Point, | - - - | 135 |
| do. Near King's Beach, | - - - | 147 |
| do. A mile N. E. of Lynn Hotel, | - - | 120 |
| do. Half a mile north of " | - - | 125 |
| do. A mile north of " " | - - | 140 |
| In Marblehead, Legg's Hill, | - - - - | 160 |
| do. Half a mile N. E. from do. | - - | 97 |
| do. Three quarters of a mile N. E. of the last, | | 105 |
| do. N. E. part of the town, | - - - | 135 |
| do. A little north of the village, | - - | 130 |
| In Marblehead, on Marblehead Neck, | - - | 137 |
| In Salem, east of Spring Pond, | - - - | 197 |
| do. N. W. part of the town, | - - - | 145 |
| do. S. E. part of the town, | - - - | 175 |
| do. A little west of South Fields, | - - | 186 |

Some of the views from the hills around Salem, and those on the promon-

tory of Marblehead, are of an imposing character. The extreme rockiness of the coast and islands, strikes the observer at first, as evidence of irreclaimable sterility. But when he sees the luxuriant vegetation of every cultivated spot, and the populousness and elegance of Salem and many of the neighboring villages, the contrast increases his pleasure.

Having thus noticed all the important hills and mountains in the State, with reference to views from their summits, I proceed briefly to sketch the picturesque scenery of particular districts. For we have not seen all that is interesting in the scenery of a country, when we have only looked over it from its elevated points. The ever varying prospects which are produced by those elevations, to one winding through the valleys among them, are often of the most romantic character.

### *The Valleys of Berkshire.*

In exemplification of this position, let us suppose an observer to pass from Williamstown southerly through New Ashford, Lanesborough, Lenox, Lee, Stockbridge, Great Barrington, and Sheffield. Till beyond New Ashford, he will be following one of the branches of the Hoosac river up the valley of Williamstown. On his right rises the broad slope of the Taconic range of mountains; while on his left, and near at hand, Saddle Mountain shoots up in imposing grandeur; and more distant, through a lateral valley, a part of the Hoosac range is visible. If it be spring, these mountain sides exhibit numerous species of trees and shrubs, emulating one another in putting on their parti-colored foliage; while here and there an Aronia, or a Cornus, is entirely clothed with white blossoms before the appearance of its leaves. If it be summer, these vast slopes are covered from base to summit with a vegetable dress, embracing every hue of green, from the dark hemlock and pine, to the almost silvery whiteness of the white oak and poplar. If it be autumn, that same foliage, now assuming almost every color of the spectrum, and of hues almost as bright, presents one of the most splendid objects in nature.

As the traveler approaches New Ashford, the hills crowd closer and closer upon his path, which winds among them in conformity with the sinuosities of the river: and a succession of romantic and Alpine beauties is constantly opening before him.

Having reached the north part of Lanesborough, he begins to descend into the valley of the Housatonic, which gradually widens before him, and ere he reaches Sheffield, presents to his view a number of most delightful villages, generally in the vicinity of fertile alluvial tracts; while on every side, mountains of various altitudes and of almost every shape, form the out-

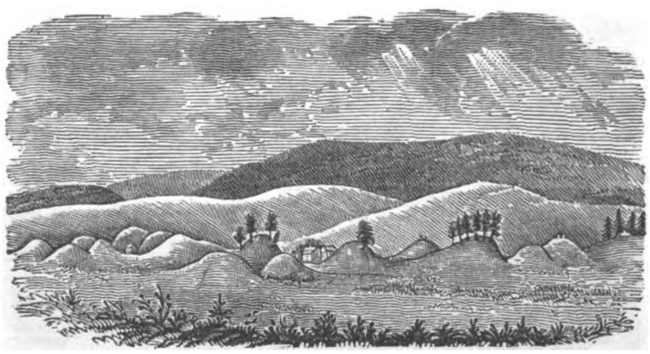
line of the landscape. Where, for instance, does the traveler meet in any part of our land with lovlier spots than Pittsfield, Lenox, Lee, Stockbridge, and Great Barrington!

Another interesting excursion in Berkshire, is to pass from Williamstown directly to Hancock. This road carries the traveler through a valley very narrow, yet walled up almost to the heavens by different ridges of the Taconic. So steep are the slopes on either hand, that cultivation is confined almost wholly to the valley. This valley opens into New York and leads to Lebanon Springs.

If in passing southerly from Williamstown, we take the left hand road, we enter the deep valley in which is situated North and South Adams, between Saddle and Hoosac Mountains. In this valley, especially in the northern part of it, one of the most curious objects that diversify the scenery, is a large number of gravelly mounds, of conical shape, which might easily be mistaken, were it not for their great size, for the work of man: but which are really the work of water: having been unquestionably produced by that diluvial agency which has essentially modified this whole region. Plate 3, exhibits several of these mounds, occurring a little west of the village of North Adams. On the left, is the northern slope of Saddle Mountain: and on the right, the southern slope of Ball Mountain: while between them at a distance, is the Taconic range. The sketch was taken a few rods west of the village, and is a northwest view.

On the east side of the valley, a little south of the village, many more of these mounds occur. Fig. 15, is a view of some of them as seen from the west, and looking directly towards Hoosac Mountain.

Fig 15.



*Diluvial Hillocks: Adams.—Mrs. Hitchcock, del.*

If we follow this valley southerly through Cheshire, we shall meet with much beautiful scenery; and if we turn still more to the left, and go to Dal-

ton, through the Valley Road, it will become extremely wild and romantic. In passing from Dalton to Lee, the country, though rougher, is quite striking. And from Lee to Stockbridge, it becomes highly picturesque.

The existence of numerous large ponds in almost every part of Berkshire, often called lakes, gives to her mountains and valleys a yet more romantic and enticing aspect. For it is universally admitted, that water forms a most important part of a good landscape. And a mountain or a village seen across a sheet of water, appears doubly beautiful. Fig. 16, is a distant view of Tyringham, as seen across a pond, from the road leading from Sheffield to Otis.

Fig. 16

*Distant View of Tyringham.—Mrs. Hitchcock, del.*

Lenox has long been celebrated for its enchanting scenery; and the beautiful ponds existing there are one of the most important constituents in its scenery. Fig. 17, is a view across what is called Smith's Pond.

Fig. 17.

*Smith's Pond: Lenox.—Miss M——, del.*

Fig. 18, is a distant view of Mount Everett, and other mountains in that direction, seen across Scott's Pond in Lenox.

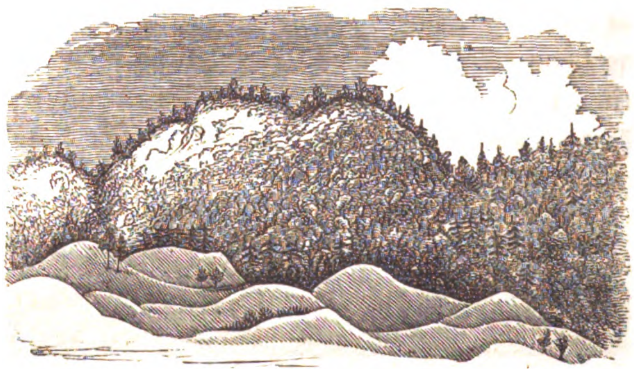
Fig. 18.

*Scott's Pond and Mts. in Mt. Washington.—Miss M——, del.*

Plate 7, is a view of Stockbridge Pond, in the north part of the town, with the surrounding scenery; and will give a good idea of this kind of landscape in Berkshire.

Some sketches have been given of diluvial elevations in the north part of Berkshire. The same phenomenon is also met with in other parts of the county. The following sketch (Fig. 19.) exhibits them at the eastern base of Monument Mountain.

Fig. 19.



*Diluvial Hillocks: Monument Mt.—Mrs. Hitchcock, del.*

### *Valley of the Connecticut.*

The circumstances that render the scenery of this valley so attractive to the man of taste, are the extent and fertility of its alluvial meadows; the precipitous boldness and irregular outline of its trap and sandstone ranges, already described; and the magnitude and beauty of the Connecticut, and of its principal tributaries, the Westfield and the Deerfield, winding through the secondary basins, which their waters or other agencies have produced.

Let such a region as this be sprinkled over with villages like Longmeadow, Springfield, West Springfield, South Hadley, Amherst, Sunderland, Northampton, Hadley, Hatfield, Deerfield, Greenfield, and Northfield, and it needs the inspiration of poetry to describe its beauties. Unfortunately, however, the valley of the Connecticut remains yet to be described.

Several of the villages above named are sufficiently elevated to overlook the surrounding region to a considerable extent, though neighboring mountains still tower above them; and thus are combined the beauties and advantages of a location upon a hill, with those to be found in a valley. The upper terrace of Springfield, on which stands the United States Armory, is thus elevated. Still higher is South Hadley, with Holyoke and Tom half encircling it on the west and north, except where the Connecticut has opened a passage between these mountains; serving as a vista through which is disclosed at greater distance the Hoosac range; and from the hill near Mount Holyoke Female Seminary in that place, is a landscape that will suffer by comparison with few others. From the Gymnasium on Round Hill in Northampton, is one of the richest views of fertile meadows, and mountains of fantastic shape, to be found in the country. From the Gymnasium at Amherst, is a similar prospect: and from the College tower in the same place, one of wider range and more imposing features. From the Female Seminary in Greenfield, a southern prospect opens of enchanting beauty.

The opening of a new road along the banks of the Connecticut, in the northwest part of South Hadley, has brought to light (I mean, to my own eyes,) a most lovely landscape. Standing on the elevated bank and facing the northwest, you look directly up the Connecticut river, where it passes between Holyoke and Tom; those mountains rising with precipitous boldness on either side of the valley. Through the opening, the river is seen for two or three miles, enlivened by one or two lovely islands, while over the rich meadows that constitute the banks, are scattered trees, through which, half hidden, appears in the distance the village of Northampton; its more conspicuous edifices only being visible. Far beyond, and forming the remote outline of the picture, lies the broad eastern slope of the Hoosac mountains. (See Plate IV.)

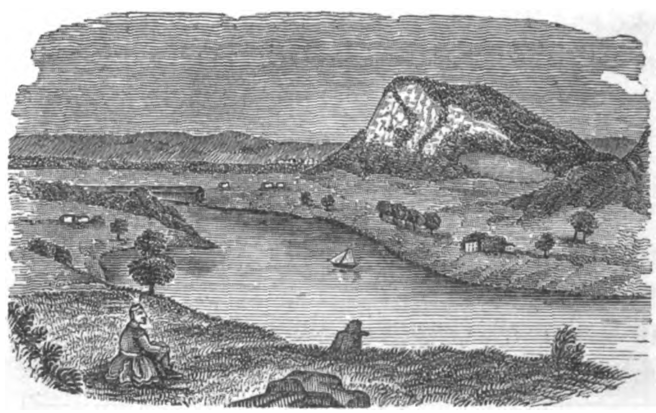
Another road has been recently opened on the banks of the Connecticut in the north part of Springfield, a mile or two below South Hadley Canal: and here, too, as you face the northwest, a landscape full of interest opens before you. In full view towards the left hand side of the picture, you have the Falls in the Connecticut and the entrance of the Canal on the north shore. A little to the right of the Canal, a well built village occupies a beautiful ampitheatre, whose elevated border is not less than 150 feet high, and mostly crowned with oakes and pines. Beyond this, at no great distance, how-

ever, Mount Tom occupies the back ground with its bold and imposing outline.

Three miles southwest of Sugar Loaf, in Deerfield, that peak presents one of the most unique views conceivable. Its outlines are so regular, that were the traveler to meet with it in Egypt, he might, at first view, regard it as indebted to human art, for its present shape. At any rate, in that country it would probably have been wrought into a second Sphinx, or some other gigantic monster. But to the student of nature it is no less interesting as the work of God. A little to the left, as seen from the place mentioned above, the southern point of the Deerfield Mountain, sometimes called North Sugar Loaf, appears, as well as the bold western front of that range for several miles; and a little to the right, across the Connecticut, Mount Toby is in full view. The sketch, Fig. 14, was taken considerably nearer to Sugar Loaf, and differs somewhat from the above description.

A little north of Sugar Loaf, and on the eastern bank of the river, a southern view of great beauty is presented. You stand upon a ridge of rocks which forms a cliff on the river bank, a short distance beyond the village of Sunderland, and there you see the river, for a mile in length, as far as Sunderland bridge: while on the opposite side of the river, an oblique view is obtained of Sugar Loaf, and the south end of Deerfield Mountain, with a distant glimpse of the primitive range of Conway and Whately. The church in the latter place is just visible. Fig. 20, will convey some idea of this Landscape.

Fig. 20.



*View down Ct. River: Sunderland.—H. J. Van Lennep, del.*

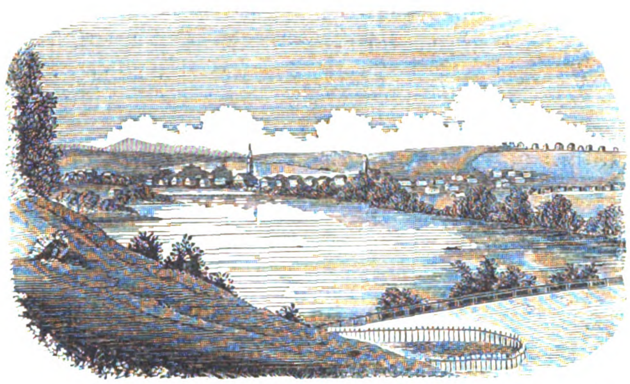
In passing south from the village of Hadley towards Holyoke, just where the road comes upon the bank of the Connecticut river, an enchanting prospects opens to the south. A lovely island covered with grass and fringed with trees, is directly before you, in the direction of the Gorge between Holyoke

and Tom; the latter being upon the right, and the former upon the left. Plate 5, will give a good idea of this spot.

The peculiar features of the Holyoke range, as seen from the valley on the north side, are shown in Plate 6. Its top will be seen to be exceedingly irregular. The depressions are valleys produced by the erosive action of water, as will be more fully explained in another place; and the principal object in presenting this sketch, is to exhibit those valleys. Still, as an interesting landscape, showing some of the peculiar features of the valley of the Connecticut, it deserves a notice in this place.

Fig. 20, is a northerly view from Wolcott Hill, about a mile south of the village in Springfield. A part of that village is shown, with the river and Mount Tom in the distance. But it conveys a very inadequate idea of the beauty of this prospect.

Fig. 21.



*View from Wolcot Hill: Springfield.—H. J. Van Lennep, del.*

## *Ravine of Westfield River.*

Westfield river has found or formed a deep passage across the whole eastern slope of the Hoosac range of Mountains, through the towns of Westfield, Russell, Blanford, Chester, and Middlefield. The ravine through which it passes, is for the most part very deep and narrow, and cuts across, not only the general direction of the mountain ranges, but across the rock strata also. Hence it might be expected that the sides of this ravine would exhibit wild and interesting scenery. Nor will this expectation be disappointed, if the traveler follows the Pontoosuc Turnpike through this defile. Hills and precipices of every shape will crowd upon his path, now approaching so near as to form a narrow gorge, and now gently retiring so as to leave room enough for some industrious farmer to erect his habitation, and gain a subsistence in the deeply embosomed glen. In passing through such a region,

the man destitute of taste will be heard speaking only of the roughness, sterility, and gloominess of the country; while the man of taste and sensibility will be absorbed in admiring its beauties and sublimities.

It is an interesting fact that the Western Rail Road from Springfield to Albany, passes through the whole extent of this ravine: and when it is completed, it will afford one of the most romantic trips in the country. Then, the citizen of Boston or Albany, in little more than half a day, will find himself among scenery as wild and Alpine as almost any in the state: and that too with little more fatigue than if he had been sitting in his own parlor. At one moment he will find himself between mountains so high and so close upon his path, and so steep withal, as almost to exclude the sun: and yet exhibiting all their original wildness. Next a narrow valley will open before him: and the comfortable farm house, with cultivated fields, will afford him an enticing picture of rural retirement and happiness.

> "Were this
> Man's only dwelling, sole appointed seat,
> First, last, and single, in the breathing world,
> It could not be more quiet: peace is here
> Or nowhere."

In another moment his eye will be arrested by the roaring cataract, plunging amid the jutting rocks. And then will the rocks close in upon his path, standing upon either hand in frowning attitude, and crowned by overhanging trees, which only partially hide the ragged rocks upon the vast and steep slopes. Down these slospes, at intervals, he will hear the roaring cataract descend, while all along his path, will the principal stream assume a multitude of aspects: now heard only, not seen, roaring at the bottom of some dark gorge: now showing its silvery reflections among the branches of the trees: and now moving calmly through the cultivated glen.

Such essentially will this ride be over an extent of nearly 30 miles: and when the traveler descends into the valleys of Berkshire, new and wider visions of nature await him: so that even at rail road speed, I am confident this will be one of the most interesting routes in the United States.

### *Ravine and Gorge of Deerfield River.*

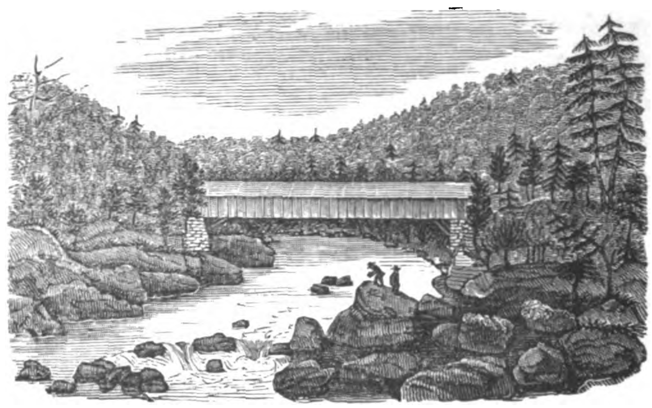
Quite as remarkable as that just described, is the gulf through which Deerfield river passes, in a southeast direction, nearly across the whole of the broad mountain range, between the Connecticut and Williamstown valleys. Perhaps the best route for visiting this ravine, is to take the turnpike road from Greenfield to Williamstown. On this road the traveler will not come upon the banks of Deerfield river, until he reaches the west part of Shelburne: but he will obtain a most delightful view of Greenfield, as he ascends the

high hills west of that place; and as to the defile, through which Deerfield river runs between Shelburne and Conway, it is so narrow, and the banks, of several hundred feet in height, are so steep, that it is difficult even on foot to find a passage: though full of romantic and sublime objects to the man who has the strength and courage to pass through it. From the west part of Shelburne, however, to the foot of the principal ridge of Hoosac mountain in Florida, a good road leads along the banks of the stream: though in a few places hard pressed between the hill and the river. In one spot it is actually sustained a hundred feet above the river, upon piles driven into the steep and naked declivity of a mountain slide. But through nearly the whole of Charlemont, the hills recede so far from the river, as to form an alluvial valley of considerable width and fertility. The loftiness of these hills, however, and the frequent openings of lateral ravines, through which the small tributaries of Deerfield river disembogue, keep the attention of the tasteful man awake. As he goes westward, these hills approach nearer and nearer to the river, become bolder in their outlines, and steeper in their declivities, till at length, in Zoar and Florida, they shoot up, sometimes a thousand feet high, in a variety of spiry and fantastic forms, and the traveler, as he looks forward, can often see no opening through which the river can find its way. The murmuring of its waters, however, at the bottom of the gulf, sometimes swelling into a roar, as they rush through some narrow defile, tell him that they have found a passage. At length the road leaves the river, and ascends tne ridge, which in the vicinity is alone denominated Hoosac Mountain, and which is here 1448 feet above the river. It is well to follow this road at least to the height of a thousand feet, in order to look back upon the wild and singular grouping of mountains, among which this river has strangely found a passage: and also to get a view of some of those vast slopes of unbroken forest, which the sides of these mountains present; and which during the twilight, are most splendid objects.

In two or three instances it has happened that I have passed along this ravine in the evening, when the moon was well above the horizon; and I can truly say, that the wildness and sublimity of the scene were thereby immensely heightened: so that I felt it to be a privilege to be thus benighted.

The bridge across Deerfield river is built in one of the wildest parts of this ravine; and having no piers, except at the extremities, it presents a singular aspect. Fig. 21, is a sketch of it with the scenery around, as seen by an observer looking down the river. The hills shown at the right and left and beyond are very precipitous and very high.

Fig. 21



*View of Zoar Bridge.—Mrs. Hitchcock, del.*

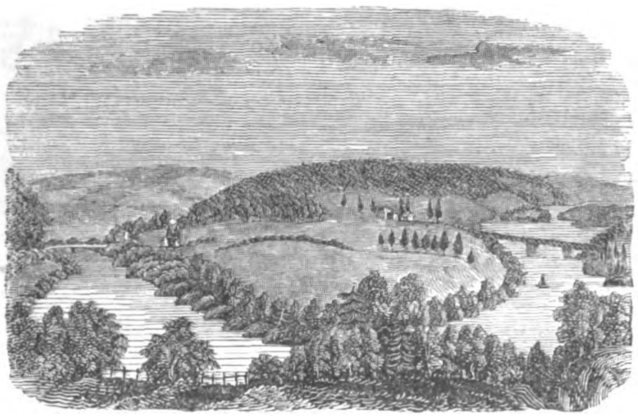
Several miles higher up Deerfield river, between Rowe and Monroe, a bridge of a similar character occupies a simular situation. At that spot there is literally no level ground on either bank: but the road down one of the longest and steepest hills in Massachusetts,* leading from Rowe to Monroe, precipitates you at once upon the bridge, and the moment you reach the opposite shore, you commence ascending a hill equally long and steep. I think the view of this bridge, as you look down the stream, is finer than that of Zoar bridge: for not more than half a mile below the bridge at the former place, and nearly in a line with the river, there rises a sharply conical mountain to the height probably of a thousand feet. But I have not been able to obtain a sketch at this spot.

Near the mouth of Deerfield River, in Deerfield, is a remarkable gorge through which that stream empties into the Connecticut. A greenstone ridge of 300 or 400 feet in height, has been cut through in some way or other, in width only sufficient to suffer the river to pass. This cut is in full view from the stage road between Deerfield and Greenfield, where it crosses Deerfield river.

Fig. 22, exhibits this gorge as seen from the eastern side of the ridge. It shows also the confluence of Deerfield and Connecticut rivers, with the romantic scenery around, and bridges across each stream: that on the right being built over the Connecticut, and that on the left over the Deerfield river. The mountains seen at a distance, through the gorge, are the primitive range passing through Shelburne. This is the most northerly point of steam navigation on the Connecticut.

* Passing down this hill soon after a heavy shower in a wagon, my horse in one place, having braced his legs firmly to hold back the load, was nevertheless slid along several feet without stepping: yet this is the best road in Massachusetts that leads into Monroe.

Fig 22.



*Confluence of Deerfield and Connecticut Rivers.—Mrs. Hitchcock, del.*

## *Valley of Worcester.*

Apart from human culture, this geographical center of Massachusetts would present no very striking attractions to the lover of natural scenery. But this valley possesses precisely those features which art is capable of rendering extremely fascinating. And there is scarcely to be met with, in this or any other country, a more charming landscape than Worcester presents, from almost any of the moderately elevated hills that surround it. The high state of agriculture in every part of the valley, and the fine taste and neatness exhibited in all the buildings of this flourishing town, with the great elegance of many edifices, and the intermingling of so many and fine shade and fruit trees, spread over the prospect beauty of a high order, on which the eye delights to linger. I have never seen, in a community of equal extent, so few marks of poverty and human degradation as in this valley. And it is this aspect of comfort and independence among all classes, that enhances greatly the pleasure with which every true American heart contemplates this scene; since it must be considered as exhibiting the happy influence of free institutions.

## *Valley of the Merrimac.*

The scenery along this river is characterized by beauty rather than sublimity. The hills and mountains are rarely precipitous or very lofty: but generally of gentle ascent and capable of cultivation to their summits. The attractions of the landscape consist of a noble river, beautiful villages, and well cultivated fields and meadows. To the man who loves to see natural scenery modified by human culture, and on every side the marks of an in-

telligent and happy population, with manufacturing establishments uncommonly flourishing, a ride down this stream on either bank, cannot but be highly interesting. And when he approaches the ocean, let him enter Newburyport from the north, across the chain bridge, and he will have before him a delightful view of one of the most beautiful towns in New England. And if he wishes still farther to witness the riches of the surrounding scenery, let him ascend the tower of the fifth church in that place, and a wide scene of beauties on the land and on the sea—natural and artificial—fills the circle of his vision.

Fig. 23, and Plate 8, are sketches taken from nearly the same spot: that is, from a point about, half way between Haverhill and East Bradford, not very elevated. On the left, and up the river, Haverhill is situated; and though partially hidden, is seen from this spot to great advantage. On the right, and down the river, the quiet village and church of East Bradford are seen: or rather, only a small part of the place is seen. But enough is visible to convey a good idea of a quiet and happy village: and I am happy to say, what can rarely be said, that the traveler finds upon acquaintance that he has not mistaken its character.

Fig. 23.

*View of Bradford from the West.—H. J. Van Lennep, del.*

From a hill a little south of Bradford meeting house, is a prospect still more extensive than from the point above mentioned. Rev. Mr. Perry informs me, that from that hill he has counted 100 meeting houses. From a hill a little farther east, the ocean is visible.

There is an exceedingly beautiful landscape before you, as you ascend the Merrimac on its south side, and come to the R. Road Depot, half a mile south of the village of Tyngsborough. The river here makes a graceful curve, which produces an equally graceful curve in the rail road, while above both, upon the left bank, a few neatly built houses make their appearance, mingled with trees. The pencil might here be employed to advantage: but I have not been able to obtain a sketch of this spot.

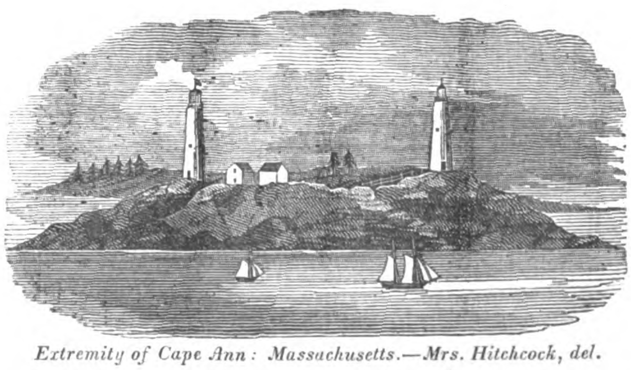
## COAST SCENERY.

The connection between geology and scenery is no where more obvious than upon a coast, exposed like that of Massachusetts, to the powerful action of the waves. There you will find the headlands and promontories almost always resulting either from the occurrence of an anticlinal axis, running into the sea, directly or obliquely, or from an alternation of harder and softer rocks; or from the accumulation of sand and shingle by the action of waves and currents. No where have these agencies been more active, nor the diverse power of resistance more obvious, than along the coast of Massachusetts. In vain have the waves for thousands of years spent their fury upon the unyielding sienite of Cape Ann and Cohasset. Not so with the slaty and softer rocks of Boston Harbor: only fragments of which remain in the form of islands to attest the former continued existence of the same formations: while the sands of Cape Cod show whither the comminuted rocks have been transported.

### *Boston Harbor.*

Let no man imagine that he has seen all that is interesting in the scenery of Massachusetts, until he has passed in various directions among the islands of Boston Harbor. Many of these islands are extremely unique in appearance, and in their varied grouping, as seen from a vessel moving onward among them, they present landscapes of the most picturesque character. Suppose a vessel to come into the harbor from the northeast. The island on which the light houses are placed, at the extremity of Cape Ann, is a striking object; chiefly because the waves have left scarcely nothing there but rock. Fig. 24, was sketched as we rushed past this island in a Steam-Boat.

Fig. 24.

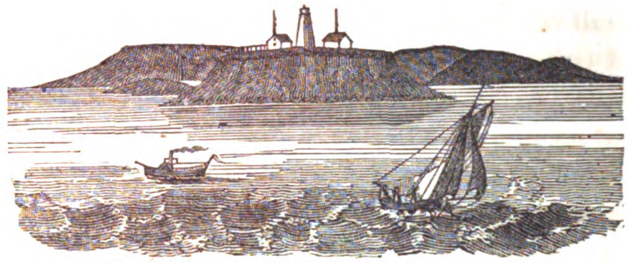


*Extremity of Cape Ann: Massachusetts.—Mrs. Hitchcock, del.*

As we entered the Harbor, Fig. 25 was sketched under similar circumstances as Fig. 24. I am not sure whether the islands represented are Calf

Island, the Great Brewster, &c. or Lovell's, Gallop's, &c. for during the few moments in which the work must be done, I had no one near me who was well acquainted with the harbor.

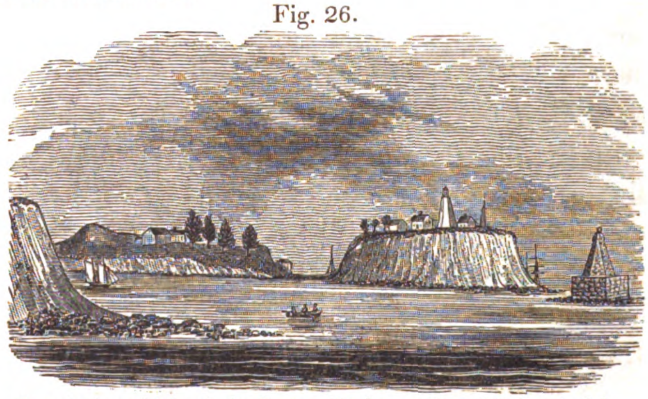
Fig. 25.



*Islands in Boston Harbor.—Mrs. Hitchcock, del.*

Wherever these islands are covered with sand or gravel, their eastern and northeastern sides present almost perpendicular cliffs, showing that the waves are wasting them away. This was shown strikingly in the last figure: and the same is seen in Fig. 26, which is a view of the islands as they appear on entering the Harbor through the usual channel from the southeast; or past the Light Houses and Point Alderton. Sketches of this sort might be multiplied greatly by a slight variation of the position. But the most important features have been exhibited.

Fig. 26.



*Denudation of Islands in Boston Harbor.—Mrs. Hitchcock, del.*

In all the views in Boston Harbor, when we look towards the city, they become doubly interesting. For a city seen from the water is usually an imposing object, when, like Boston, it slopes towards the shore, and its site is unequal. In this instance the venerable dome of the State House affords an appropriate crown for a noble city, and is visible from every part of the Harbor.

### *View from the State House.*

Upon the whole, there is not a more magnificent prospect in Massachusetts, than that from the dome of the State House in Boston; and it will bear a

comparison, it is said, with the most celebrated views of a similar kind in Europe. This noble building stands upon Beacon Hill, the highest spot in Boston: and the lantern upon its dome is about 200 feet above the harbor. From this elevation the whole of Boston, with its wharfs, shipping, and public edifices; all the islands in its harbor; the shores of the harbor lined with villages and cultivated fields; and within a circle of ten miles, not less than twenty villages, containing, with Boston, more than 150,000 inhabitants, are here surveyed at a glance. Almost every dwelling of this numerous population, is, indeed, visible: and it is rare to see in a circle of so small extent, as many edifices so elegant; and so few that indicate extreme poverty and wretchedness. So richly cultivated is the vicinity of Boston, that it has the appearance of a vast garden. Yet we do not see here the traces of that vandal spirit, which, in so many parts of our land, is making sad havoc with our groves and shade trees; but enough have been spared or planted in this vicinity to give a refreshing and luxuriant aspect to the scenery.

The political and moral considerations which irresistibly force themselves on the mind when contemplating such a scene, cannot fail greatly to increase the pleasure of the observer. What a drawback upon that pleasure must it be, when the traveler is compelled to say, as he cannot but say, when gazing on a large proportion of the interesting scenery of the eastern continent,

'Art, glory, freedom fails, though Nature still is fair.'

On the contrary, how refreshing to the benevolent spirit, as it surveys from this eminence the dwellings of 150,000 human beings, to be assured that there is not a slave among them all; and that could the eye take in every part of the Commonwealth, it would read on every door post the inscription, 'all men are born free and equal;' a maxim which exerts a talismanic influence in defending the feeblest inmate against oppression. Nor should the observer forget, that this same maxim forms the basis of every law originating from the edifice on which he stands; and that it is not licentious liberty that is here enjoyed; but liberty guarded by law, and sustained by law: and that it is the general prevalence of knowledge and virtue in the community, that renders it possible to sustain a proper balance between liberty and law. Foreign nations may predict that our beautiful republican system will be ephemeral. It will, indeed, pass away whenever unprincipled ignorance shall be permitted to bear sway. But so long as intelligence and moral principle predominate in the community, the ark of liberty is safe. At any rate, it is certain that we do now enjoy the blessings of freedom, and the means, widely diffused, of intellectual, moral, and religious cultivation. As a consequence, contentment, competence, and happiness, are found even among the lowest classes in the community. The traveler of a benevolent heart

will rejoice to see, as he wanders over the hills and valleys of our Commonwealth, how very few in the community have not all the essential means of human happiness within their reach. He need not fear being detained for days in the wildest and most secluded parts of the State. For scarcely will he find the hut, where if really needing shelter, he will not find a welcome, and all that a temperate man needs to make him comfortable. A man who has frequently been thrown into such situations, or in other words, has had opportunity to learn the character and circumstances of the lowest as well as the highest classes in our community, will find his pleasure greatly heightened in surveying our scenery. Let us hope that succeeding travelers, through many generations, may not be deprived of this same happiness; and instead of indulging in gloomy predictions of the downfall of liberty, let every man strive to form and retain that intellectual, moral, and religious character, which is its only effectual support.

But I fear that I am wandering beyond my appropriate sphere, by these remarks. I proceed to notice some other objects worthy the attention of the man of leisure and taste.

*New Bedford seen from its Harbor.*

This flourishing place, already wearing the aspect of a populous city, is seen to great advantage in sailing up its harbor. As the ground on which it is built slopes towards the water, the various objects of interest are thus brought into view, rising above one another in a distinct and pleasing manner.

*Narraganset and Mount Hope Bays.*

An excursion from Taunton to Newport, Rhode Island, down Taunton river, and Mount Hope Bay, and especially from Providence to Newport along Narraganset Bay, conducts the traveler among scenery of great beauty and loveliness. The fertility of most of the country, the neat villages along the way, the numerous irregular contractions and expansions of these bays, forming capes, isthmuses, promontories, bays and harbors, in miniature; the islands that are occasionally interspersed, and the interesting historical associations connected with that region, conspire to keep the attention alive and to gratify the taste. Mount Hope, the granite watch tower of the celebrated Sachem Phillip, still commands a fine prospect of the surrounding region; and we see at once why that sagacious chieftain selected this place for his retreat.

The north and south shores of Massachusetts Bay present much scenery of such a sui generis or peculiar character, as to render it extremely interesting to one unaccustomed to it. As a general fact, there is so great a contrast in the appearance of the two capes which form this Bay, that a visit to the

one, only prepares the way for rendering more interesting an excursion to the other. We will suppose the traveler to start from Boston and first proceed along the north shore of the Bay.

*Nahant.*

He will not fail to visit Nahant; which will be the first place of peculiar interest he will meet along this coast. It is a bold rocky promontory, connected by a low sandy neck of land with Lynn: or rather, it consists of two islands connected together, and with the main land, by ridges of sand and pebbles. At low water, a perfectly smooth beach of the finest sand is laid bare, which constitutes the road from the mainland; and this sand is so firmly compacted by the perpetual beating of the waves of the Atlantic, that neither horse nor carriage make scarcely a perceptible impression. Hence the ride becomes a delightful one; and although the promontory itself has a very barren and desolate appearance, yet the singularity of the surrounding scenery, the neatness of the houses, built in a peculiar style, and the wide extent of the horizon, conspire to render the prospect during the summer of a most attractive character. It is a place of great resort in the warmer months, and a steamboat plies daily between this place and Boston. The vicinity of the spacious hotel at Nahant is very interesting to the geologist: but the particular characteristics of the rocks must be deferred to a subsequent part of this Report.

*View from Saugus towards the Ocean.*

A little east of the meeting house in the retired village of Saugus, is a small but singular conical eminence, from whose summit the delightful view exhibited on Plate 9, opens towards the ocean. The objects most interesting are the river, with its graceful meanders, a part of Lynn near its mouth, the ocean beyond, and the promontory of Nahant.

*Cape Ann.*

I have spoken of the rockiness of the coast in the vicinity of Salem. As we proceed towards Gloucester, which occupies all of what is properly called Cape Ann, the ledges multiply; and on the Cape the forests are mostly cut down, while the surface is almost literally covered, either with rocks in place, or with bowlders of every size. In the northwestern part of Gloucester particularly, the soil is almost wholly concealed by the countless number of these rounded masses. Over nearly all the Cape, indeed, sienite of every description meets the eye in immense quantities; and the traveler naturally enquires whither the soil has been carried, which must once have covered the rocks; and what mighty flood of waters could have swept over this region with the fury requisite to produce such devastation. Scenery of this kind, would be regarded as extremely dreary, were not the desolation

carried to such an extent as to be interesting by its novelty. It is scarcely possible for any man, however little interested in the *bizarre* of natural scenery, to traverse this region for the first time, without having his attention forcibly and constantly directed to the landscape around him. And hence this must be one of the best excursions for those afflicted with ennui, that can be found.

It is not rocks alone that form striking objects upon Cape Ann. For in some places these are covered by pure white sand: producing a striking contrast to the rocky cliffs and bowlders. Fig. 27 is a northerly view of Squam on the northeast part of Cape Ann; and it exhibits both kinds of scenery at one *coup d'œil.*

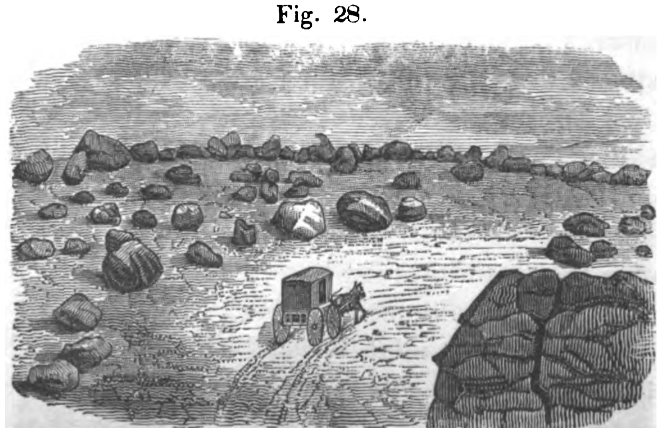
Fig. 27.

*View of Squam in Gloucester.—H. J. Van Lennep, del.*

The sketch shown in Fig. 28 was taken a little south from the spot where Fig. 27 was drawn; and on the road leading to Gloucester. It will convey an idea of the appearance of hundreds of acres in that part of Gloucester. What a complete image does it present of perfect barrenness and desolation.

"Far and near
We have an image of the pristine earth,
The planet in its nakedness."

Fig. 28.



*Sketch on Cape Ann.—H. J. Van Lennep, del.*

## *Nantasket Beach and Hull.*

Suppose now the traveler, for the sake of amusement or recreation, should proceed along the south shore of Boston Harbor and Massachusetts Bay. Admiring as he passes the scenery of Dorchester, Quincy, and Hingham, the first objects that will have a peculiar claim upon his attention, are Nantasket Beach and Hull.

To say nothing of the rocks, which at the head of this beach constitute almost the entire surface, rivaling even Cape Ann in this respect, and which on the shore present a remarkable and elegant variety of colors, the beach itself, not less than four or five miles in extent, is much more interesting than that leading to Nahant. The Light House and the Brewster and other islands in view, as one advances toward Hull, are picturesque objects; and then the pleasant and sunny situation of the little village of Hull, furnishes a convenient resting place for the traveler.

In proceeding from this beach to Cape Cod, the observer should not fail to pass along the north shore of Cohasset—the most rocky place perhaps in the Commonwealth.

## *Cape Cod.*

But after passing Duxbury, the region of sand and gravel commences; and to Provincetown, the extremity of Cape Cod, no genuine ledge of rocks appears; although bowlders of every size, over the greater part of the distance, are common.

The dunes or sand hills, which are often nearly or quite barren of vegetation, and of snowy whiteness, forcibly attract the attention on account of their peculiarity: while the numerous windmills and vats along the shore, for the manufacture of salt, are scarcely less interesting to one not familiar with such processes. As we approach the extremity of the Cape, the sand and the barrenness increase; and in not a few places, it would need only a party of Bedouins to cross the traveler's path to make him feel that he was in the depths of an Arabian or Lybian desert. Very different from Bedouins, however, will he find the inhabitants of Cape Cod. In the midst of the sands he will meet many an oasis, where comfortable and not unfrequently pleasant villages have sprung up, inhabited by a people of mild and obliging disposition, and not deficient in intelligence. A large proportion of the houses on the Cape are, indeed, but one story high. Yet they are for the most part convenient and comfortable; exhibiting the marks of a thrift and independence which one would not expect, when he considers the gen-

eral barrenness of the landscape. I could name several parts of Massachusetts, where the marks of poverty are far more striking than on Cape Cod.

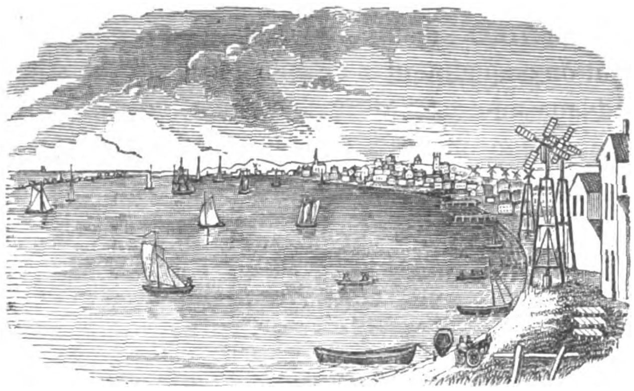
The sand is so yielding that the traveler will find it more convenient to leave his carriage 20 or 30 miles short of the extremity of the Cape, and proceed on horseback: though it is practicable to proceed with wheels. But for seven or eight miles before reaching Provincetown, he must find his way along the margin of a salt marsh during ebb tide. During flood tide, he will be forced to wade through the loose and deep sand higher up the beach. The view of Provincetown along this course, is so peculiar, that the traveler feels himself amply repaid for his labor. A semicircular bay is enclosed on the north and east by a sandy beach and low sand hills almost destitute of vegetation, which seem to threaten, and do in fact threaten, to bury the village, and to fill the harbor. The houses, for a population not much short of 2000, are erected on the margin of this bay, just above the reach of the tide, and at the foot of the sand hills. These dwellings are almost as destitute of order in their position, as it is possible they should be: only one regular street, wide enough for carriages to pass, being found here.* But the most singular object in this place, is the numerous windmills erected between the dwellings and the harbor, for pumping up the water into reservoirs for evaporation. When set in brisk motion by the wind, standing as they do between the traveler and the dwellings, as he comes from the south, they give to the village a most singular aspect.

The view of this town, which is given in Fig. 29, was taken from a point a few rods beyond the southeastern extremity of the village, and will give some idea, though an imperfect one, of those peculiar features of this landscape that have just been described. They are so unique and different from anything in the interior of New England, that a visit to this place by land in the summer would probably in many cases prove as effectual a remedy for ennui and other fashionable complaints, as a resort to Ballston or Saratoga. A daily stage goes down the Cape as far as Orleans: and from thence every other day a waggon proceeds to Provincetown; which might convey two or three passengers. From that place, packets run at irregular but not long intervals to Boston in a few hours. I do not doubt but this excursion, when the route becomes better known, will become quite

* A few years since even this did not exist here, and the whole place could scarcely have been more irregular, had the buildings all been constructed in the air and committed to a whirlwind to locate. That portion of the surplus revenue of the United States which fell to this town was very wisely expended in constructing a decent, though very crooked street through the whole town, and in forming a side-walk of plank. Scarcely anything could have contributed more to the comfort and appearance of the place. In the town meeting in which it was decided to make this application of the surplus revenue, one of the speakers remarked, that this money had proved a bone of contention in most places, and for his part he thought the best place for a bone was under foot, and therefore should vote for constructing a side walk with these funds.

common: and as the travel is increased, the means of transportation will be improved. Should it become sufficient to require a steam boat from Provincetown to Boston, I can hardly think of a route that would be more likely to interest and profit a large part of the community.

Fig. 29.



*View of Provincetown.—Mrs. Hitchcock, del.*

In crossing the sands of the Cape, I noticed a singular mirage or deception, which was also observed by my traveling companions. In Orleans, for instance, where the ocean is within a short distance on either hand, we seemed to be ascending at an angle of three or four degrees; nor was I convinced that such was not the case, until turning about I perceived that a similar ascent appeared in the road just passed over. I shall not attempt to explain this optical deception: but merely remark, that it is probably of the same kind, as that observed by Humboldt, on the Pampas of Venezuela; "all around us," says he, "the plains seemed to ascend towards the sky."

In crossing the island of Nantucket, in company with Dr. Swift of that place, I noticed the same phenomenon, though there less striking. After wards, I saw it for miles on the plain in the southeastern part of Martha's Vineyard. In the latter case, the plain was covered with low shrub oaks.

## *Nantucket and Martha's Vineyard.*

If the traveler wishes to enjoy more of the peculiar scenery of Cape Cod, with some interesting variations, let him pass over to Nantucket and Martha's Vineyard. The former island he will find to be an extended plain, 15 miles in its longest direction, and but slightly elevated above the ocean; containing scarcely a tree, or a shrub of much size, except in the immediate

vicinity of the village. Scarcely a dwelling will meet his eye, out of the town, except a few uninhabited huts, scattered along the desolate shore, as a refuge to the shipwrecked sailor. Yet from 12000 to 14000 sheep, and 500 cows find nourishment on this island; and in not a few places, especially in the immediate vicinity of the town, may be seen tracts of land of superior fertility. It will strike the traveler at once, as an interesting monument of industry, that nearly every part of the dwellings, stores, &c., for the accommodation of more than 7000 inhabitants, must have been transported from the Continent. And on acquaintance, he will find that they still retain the characteristics of industry and hospitality, for which they have long been known; and that the usual concomitants of these virtues, general intelligence and strong local attachments, are not wanting.

### *Gay Head.*

The most interesting spot on Martha's Vineyard is Gay Head; which constitutes the western extremity of this island, and consists of clays and sands of various colors. Its height cannot be more than 150 feet; yet its variegated aspect, and the richness of its colors, render it a striking and even splendid object, when seen from the ocean. The clays are red, blue and white; the sands, white and yellow; and the lignite, black; and each of these substances is abundant enough to be seen several miles distant, arranged in general in inclined strata; though from being unequally worn away, apparently mixed without much order. The top of the cliff is crowned by a light house, which commands an extensive prospect. Scarcely a tree is to be seen on this part of the island. It is owned and inhabited by the descendants of the Indian tribes, that once possessed the whole island. It will be seen in the subsequent part of my Report, that this spot possesses peculiar attractions for the geologist and mineralogist.

I have felt quite desirous of obtaining a good drawing of Gay Head, as seen from the ocean: but have never been accompanied thither by an artist except once; and then the wind was too powerful to allow putting off in an open boat. All, therefore, that could be done, was to take an oblique view of the cliff, as seen from a high bluff near its southern part, which advances several rods beyond the general surface. Fig. 30, exhibits the northern and greater part of the Head, with the Light House, and beyond this on the right, an Indian school house; and still more distant, cliffs in Chilmark: while on the left, beyond the water, are seen some of the Elizabeth Islands and a part of Falmouth. Every lover of natural scenery would be delighted to visit this spot. There is nothing to compare with it in New England;

and probably not in this country. It corresponds well with the cliffs of the Isle of Wight on the English coast.*

Fig. 30.

*Gay Head. Mrs. Hitchcock, del.*

## WATER FALLS.

We have a few water falls in Massachusetts of sufficient magnitude to be denominated cataracts. And as we might expect in a mountainous region, cascades are numerous.

### *Turner's Falls.*

These exist in Connecticut river, near the point where the towns of Montague, Gill, and Greenfield meet. They are by far the most interesting water fall in the State; and I think I may safely say in New England. At least, to my taste, the much broader sheet of water, the higher perpendicular descent, and the equally romantic scenery of the surrounding country, give to this cataract a much higher interest, than is excited by a view of the more celebrated Bellow's Falls on the same river, in Walpole, New Hampshire: and probably the latter are generally regarded as the most striking object of this kind in New England.

Above Turner's Falls, the Connecticut for about three miles, pursues a course nearly northwest, through a region scarcely yet disturbed by cultivation; and all this distance it is as placid as a mountain lake, even to the

* As it is extremely difficult to land with a good sized boat within several miles of Gay Head, the best way, though the most expensive, of going thither upon the whole, is, to take passage at New Bedford in the steam boat, which touches at the other extremity of the Island, where a carriage can be procured to go to the Head. It is to be regretted, however, that the road for the last five or six miles is so rough and crooked, that a guide and considerable courage are indispensable. Not less than 17 pairs of bars must be gone through. At the Head, the traveler can be very comfortably lodged with an Indian by the name of Thomas Cooper. So far as I have had intercourse with the aboriginees residing here, I have been very favorably impressed with their shrewdness, industry, temperance, and general moral and religious character as a community.

verge of the cataract. Here an artificial dam has been erected, more than a thousand feet long, resting near the center upon two small islands. Over this dam the water leaps more than 30 feet perpendicularly; and for half a mile continues descending rapidly and foaming along its course. One hundred rods below the falls, the stream strikes directly against a lofty greenstone ridge, by which it is compelled to change its course towards the south at least a quarter of a circle.

The proper point for viewing Turner's Falls, is from the road leading to Greenfield, on the north shore, perhaps 50 rods below the cataract. Here from elevated ground, you have directly before you, the principal fall, intersected near the center by two small rocky islands, which are crowned by trees and brushwood. The observer perceives at once that Niagara is before him in miniature. These islands may be reached by a canoe from above the falls in perfect safety. Fifty rods below the cataract, a third most romantic little island lifts its evergreen head, an image of peace and security, in the midst of the agitated and foaming waters, swiftly gliding by. The placid aspect of the waters above the fall, calmly emerging from the moderately elevated and wooded hills at a distance, is finely contrasted with its foam and tumult below the cataract.

The country around these falls is but little cultivated. On the opposite side of the river the observer will, indeed, perceive a few dwellings and the head of a canal: But a little beyond, wooded elevations, chiefly covered with evergreens, terminate the landscape; while in every other direction, the scenery is still more wild and unreclaimed from a state of nature.

A sailing excursion from the falls, three miles up the stream, has all the attractions of a passage over a mountain lake, and probably the coves along the shore furnish as good spots for fishing as now exist in the river. The geologist too, will find the vicinity of these falls full of interest—but of this more hereafter.

Three miles above Turner's Falls, Miller's river empties into the Connecticut, over a dam about ten feet high. I apprehend these falls have been confounded with Turner's; and hence the latter are sometimes called Miller's Falls. They cannot, however, be said to have as yet any well established name. For a reason which will be mentioned below, I ventured some eighteen years since, in a geological account which I published of the Connecticut valley, to denominate these falls, *Turner's Falls;* and Gen. Hoyt, in his History of the Indian Wars, has given them the same designation. I am aware, however, how very difficult it is to make popular and prevalent, a new name for any natural object; although in the present case, I doubt not, that every man acquainted with the history of this spot, would say that to prefix the name of Capt. Turner to this cataract, is appropriate and just.

About 170 years ago, a party of Philip's Indians, having joined those living in the vicinity, resorted to these falls to take fish. On the 17th of May, Capt. Turner, from Boston, marched from Hatfield, with 150 men, and came by surprise upon the Indian camp the next morning at day light. The Indians being totally unprepared for an attack, fled in every direction; some springing into their canoes without paddles, were precipitated over the falls and dashed in pieces. Three hundred Indians, and but one white man were killed. Yet the Indians who escaped, being joined by others, fell upon Turner's party as they were returning, and made a dreadful slaughter among them; killing thirty seven, among whom was Capt. Turner. Will not the public do the justice to this brave but unfortunate officer, to send down his name to posterity, associated with that of the spot where he conquered and fell!

During high water, the roar of Turner's Falls may be heard from six to ten miles. The magnificence of the cataract is greatly heightened at such a season.

In order to visit Turner's Falls, one must turn aside from every great public road; and although but four miles from the village of Greenfield, this circumstance shows why they are so seldom resorted to by travelers. They are exhibited on Plate 10, as seen from the north shore below the cataract. Since the sketch was taken, I believe some few alterations have been made in the buildings upon the opposite shore.

### *Holyoke's Falls.*

For two miles below Turner's Falls, the river presses hard upon a trap ridge, whose base is thus almost entirely denuded of soil, and the bed of the stream is too rocky and to rapid too admit of navigation; so that scarcely a spot in the state can be found so unfrequented as this. It was not till since the publication of my former reports, that I discovered the existence of another cataract about a mile below Turner's Falls, which, although less interesting than Turner's, is yet worthy of notice. The river is there divided by an island, as at Turner's Falls: but it is only the fall on the eastern branch that can be seen to advantage.

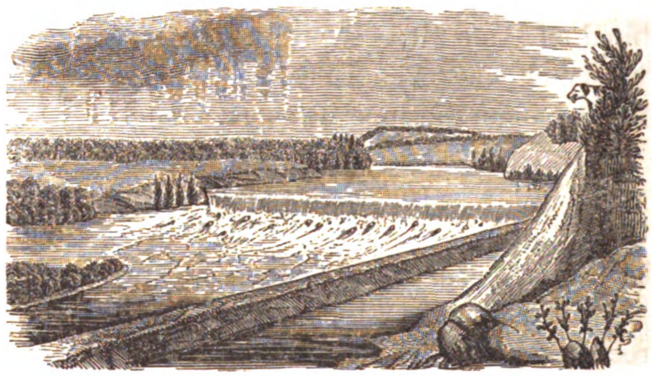
Plate 11, shows these falls as they appear upon the shore of the river a few rods south. Although the descent of the water is small, yet the projecting rocks from the bottom and the banks, the undisturbed forest trees upon the shores, and the distant blue hills, render the view highly romantic and deserving the attention of the man of taste. The road from Greenfield to Boston passess within half a mile of the spot, and the traveler can leave his carriage at the public house near the bridge over Connecticut river.

Associated with Capt. Turner in the expedition against the Indians at the upper falls already described, was Capt. Holyoke of Springfield. During the engagement at the falls, he was particularly forward and courageous; having it is said, killed five of the enemy with his own hand. And after Turner's reverse, Holyoke covered the rear; and after Turner's death, he assumed the command and brought off the party successfully. If, therefore, Turner deserves to have his name associated with the upper falls, certainly none will refuse the honor to Holyoke, which I now propose, by connecting his name with the lower falls.

### *Mitineaque Falls.*

About a mile west of the village of West Springfield, Agawam river falls a few feet, and recently a dam has been erected of considerable height, so as to make a cataract of no small interest. The Spot is also attractive to the geologist, as the subsequent parts of my Report will show. Fig. 31, will convey a good idea of the general features of this spot.

Fig. 31.



*Mitineaque Falls: W. Springfield.—H. J. Van Lennep, del.*

### *Salmon Falls.*

Following up Agawam river beyond Westfield, (where it takes the name of Westfield river,) until we come to the place where it issues from the mountains in Russell, and we shall there find Salmon Falls. It is a romantic spot; although the fall itself is not very imposing. But the rugged rocky island at the precipice, the Feeder to the Farmington and Northampton Canal, which is here commenced, and the grandeur of the surrounding mountains, powerfully awaken and keep alive the attention. Fig. 32, conveys but a poor idea of these falls, because it was taken at a point from which only a part of the objects above alluded to could be seen, and also because it is not very accurate.

Fig. 32.

*Salmon Falls, on Westfield River.*

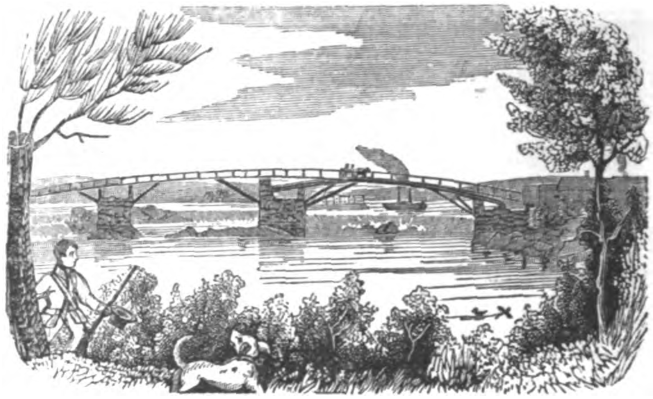
### *Great Falls.*

A few miles beyond Salmon Falls, but still within the bounds of Russell, another cataract of still greater interest exists on Westfield River. This is called Great Falls; and is at Gould's Mills, near the northwest corner of Russell. The bed and banks of the river here, as well as at Salmon Falls, are composed mostly of white coarse grained granite. This, as well as the slate rocks connected with it, is swept of soil, and deeply worn down in such a manner as to leave masses projecting from the sides and bottom of the river. At high water the falls are very imposing, and at low water the rocks just described, which show the powerful effects of water upon the solid frame work of the globe, are scarcely less interesting. The mountains around and ahead, as we look up the stream, are of the usual magnificent character exhibited in this ravine. Plate 12 exhibits Great Falls, as seen from a projecting point several rods below, on the eastern bank. The rail road cars are placed where the road is located; and where they will doubtless be seen in the autumn of 1840.

### *Pawtucket Falls on Merrimac River.*

Pawtucket Falls, though of no great elevation, have given rise to the city of Lowell: for without them no water privilege would exist there. A little below the falls, a bridge is built across the river; and a little above them, is the head of Middlesex Canal. The bottom of the stream is composed of rocks, whose ragged aspect is finely contrasted with the smooth water and beautiful banks extending several miles above the city. Fig. 33, was sketched considerably below the bridge on the north bank.

Fig. 33.



*Pawtucket Falls: Lowell.—H. J. Van Lennep, del.*

Near the mouth of Concord river, which empties into the Merrimac, a little to the east of Lowell, is some scenery and one or two cascades well worthy of a visit. The deep cut for the rail road through the mica slate, a little south of the city, may be also mentioned as a place of interest, especially to the geologist.

### *Spicket Falls.*

Spicket river is a tributary of the Merrimac on the north side; and a few miles above its mouth, near the center of Methuen, it falls 30 feet; partly however over an artificial dam. A flourishing manufacturing village has grown up around these falls: and although somewhat modified in appearance by the hand of man, they form an object of no little interest. Fig. 34, will give an idea of their prominent features.

Fig. 34.

*Spicket Falls: Methuen.—H. J. Van Lennep, del.*

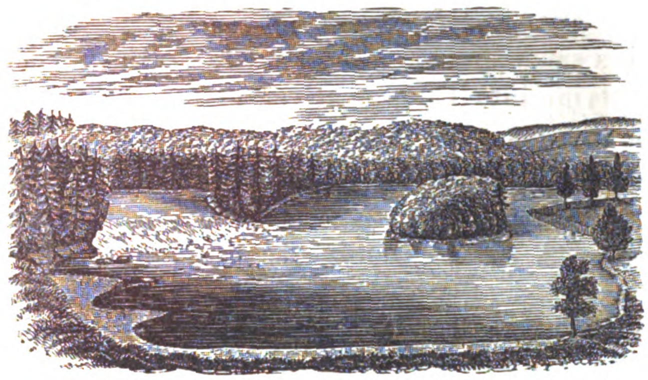
*Falls in Fall River.*

Fall River is a small stream on the borders of Rhode Island, in the county of Bristol, emptying into Taunton River at the village of the same name. It takes its rise in a pond only a mile or two back of the town : but being precipitated down the bank at least a hundred feet, in the distance of as many rods, it forms a watèr privilege of great power, which has been most thoroughly improved. The extensive factories built of the excellent granite which is here so abundant, are usually placed directly across the stream; so that when the whole of the water has been made to turn the machinery of one establishment, it passes into another immediately below it, to perform the same office; and so on, till it reaches Taunton river. The fall, therefore, which must originally have formed a beautiful cascade, is almost entirely lost. But when we see how beautiful and extensive a village has been the consequence, we submit without murmuring to the loss. And besides, the fine view of Mount Hope Bay, with numerous other objects bordering the river, make the prospect from this village a delightful one.

*Indian Orchard and Falls on Chicopee River.*

In the vicinity of Putt's Bridge, which crosses the Chicopee river from the northeast part of Springfield into the southwest part of Ludlow, is a manufacturing village; and at least two interesting falls of water. The principal one lies half a mile down the stream from the village, and the spot goes by the name of Indian Orchard. Fig. 35, is a view of this spot from the high bank on the north shore, a little below the falls.—Standing there you see the water pouring down a steep though not perpendicular declivity of sandstone, and issuing from a deep gorge which its waters have worn in the rock. Just below the falls, the waters form a beautiful basin, with a lovely island near its center, and surrounded on the south and west by an unbroken forest; so that at this place you scarcely see the marks of human agency at all. The contrast between the waters as they they issue foaming and dashing from the gorge and down the steep, and those same waters as they lie almost without a ruffle in the basin below, beautifully reflecting the surrounding hills and trees, is extremely pleasing.

Fig. 35.



*Indian Orchard: Springfield.—H. J. Van Lennep, del.*

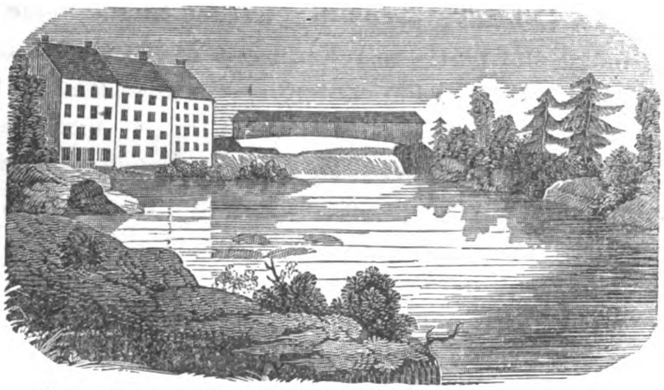
If we quit the spot whence the above was taken, and approach the place where the waters issue from the gulf which they have cut in the rocks, we shall find on the north side, an overhanging precipice of some 50 or 60 feet, whose edge it needs some nerve to approach, and steadily to look over. Fig. 36, is intended to show the manner in which this sandstone cliff hangs over the water.

Fig 36

*Falls at Indian Orchard.—H. J. Van Lennep, del.*

It is interesting to follow the deep windings of the river from these falls to Putt's Bridge, overshadowed as it is by thick forests most of the distance, and often presenting romantic views. When we reach the first factory upon its bank, from a point of land projecting into the river, a little below the buildings, we get a pleasing view of another fall with Putt's Bridge passing over the river in the vicinity. And though to the lover of nature in her wildness, the buildings upon the banks detract from the beauty of this spot, yet the landscape is by no means to be despised. Fig. 37, is a representation of it as seen from the point above named.

Fig. 37.



*View at Putt's Bridge: Ludlow.—H. J. Van Lennep, del.*

Upon the whole, Indian Orchard and its vicinity are well worth the attention of the man of taste. A half day may be spent here in a most agreeable manner, and I am surprised that it is not more known and visited.

### *Gorges and Falls in Royalston.*

There are at least three water falls connected with deep gorges in Royalston, that are well worthy the attention of those who are fond of wild natural scenery. About a mile west of the meeting house and center of the town, is a deep valley running north and south, nearly across the town. Near the meeting house is a pond which empties itself into this valley by plunging rapidly down a steep declivity, which must be 800 or 1000 feet high. It there empties into another large pond, or rather a remarkable expansion of a small tributary of Millers' river. At one part of the descent of the brook above named, it falls at least 200 feet by several leaps, within a distance of a few rods, forming several very beautiful cascades. Here the original forests have not been disturbed. The trees overhang the murmuring waters, half concealing the stream, while broken trunks are plunged across it in all positions.

In the extreme northwest part of the town, on the farm of Calvin Forbes, a gorge and cascade exist of still greater interest: one of the finest indeed in the state. The stream is not more than 10 feet wide at the spot, but it descends 45 feet at a single leap, into a large basin, which from its top has been excavated by the erosion of the waters. The sides, to the height of 50 or 60 feet, are formed of solid rocks; now retreating and now projecting: crowned at their summit by trees. Many of these lean over the gulf, or have fallen across it; so that upon the whole, the scene is one of great wildness and interest.

Plate 13, exhibits this spot as seen from below the falls. It certainly deserves a name; and until a better one shall be proposed, I would suggest that of *The Royal Cascade;* partly in reference to the name of the town in which it is situated, and partly in reference to its *royal* character.

Two miles south of Royalston center, on the road leading to Athol, is another cascade on a larger stream. Its width indeed, must be as much as 25 feet, and the depth considerable. In a short distance the water here descends, at several successive leaps, as much as 200 feet, between high walls of gneiss and granite. Towards the upper part of the descent, several mills are erected: but a small part only of the water power is employed. Below the mills, the stream passes into the woods: and towards the lowest part of the descent, we get a single view of two falls of about 25 feet each. This is sketched on Fig. 38, from which it appears that there is more of beauty and less of wildness at this spot than at the Royal Cascade. This stream also has been, and still more extensively can be, applied to useful purposes. Perhaps therefore, considering the character of our political institutions, and our well known reputation for *utilitarian* tendencies, this, rather in contrast to the Royal Cascade, may be denominated the *Republican Cascade.* But if I can induce persons of taste and leisure to visit it, I care but little for the name.

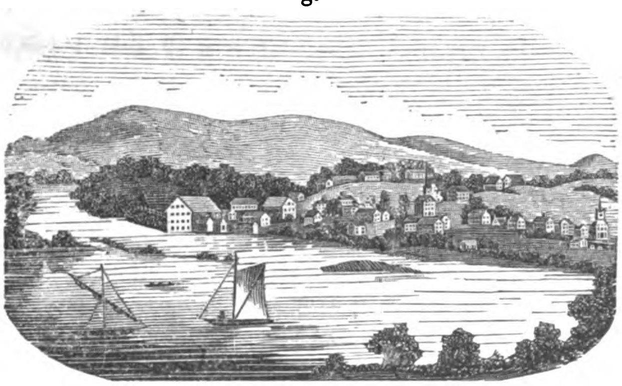
Fig. 38.

*Cascade: Royalston.—H. J. Van Lennep, del.*

### *Falls at South Hadley in Connecticut River.*

The descent of the water here being but a few feet, these falls do not in themselves possess any great interest; and yet, as one of the objects in the beautiful landscape which has already been described as existing at this place, their absence would be sensibly felt by the man of taste. Fig. 39, will convey some idea of this spot.

Fig. 39.



South Hadley Canal.—Mrs. Hitchcock, del.

*Shelburne Falls.*

These occur in Deerfield river where it enters the narrowest part of that deep ravine in the primary strata, between Shelburne and Conway, which has been already described. As a mere object of scenery they are not so striking as Turner's Falls; though they exhibit not a little of wildness and sublimity; and they are especially worth a visit from the geologist, as affording a good exhibition of the effects of a mountain torrent upon the hardest of rocks.

*The Gorge, or Glen in Leyden.*

In the south part of Leyden, a large brook has worn a passage from 10 to 20 feet wide, and from 30 to 50 feet deep, in the strata of argillo-micaceous slate. The layers of the slate are nearly perpendicular, and it is traversed by numerous cross seams, into which the water penetrates, and in winter freezes, expands, and thus assists in removing mass after mass of the rock from its place. A slight inspection of the place will show that such was the mode of its formation; although one cannot but perceive that a great length of time was requisite for the whole process. There is not the slightest appearance of any convulsion at this place, since the original elevation of the strata. The correspondence between the salient and reentering angles on opposite sides of this stream, is no greater than exists in every stream; and all the appearances at the place forbid the supposition often made that these sides have been separated from each other. The length of this gorge is from 30 to 40 rods. Above is a deep glen; and below, the stream passes through a deep ravine. Two water falls near the lower part of the gorge add much to the interest of this spot. And although the geological chronometer here exhibited, is to the reflecting mind, its greatest attraction: yet the

wildness and ruggedness of the scenery draw not a few visitors. The term "glen," usually applied to this spot, is certainly a misnomer. For it is a gorge connecting a glen with a ravine, Fig. 40, was sketched below the principal cascade.

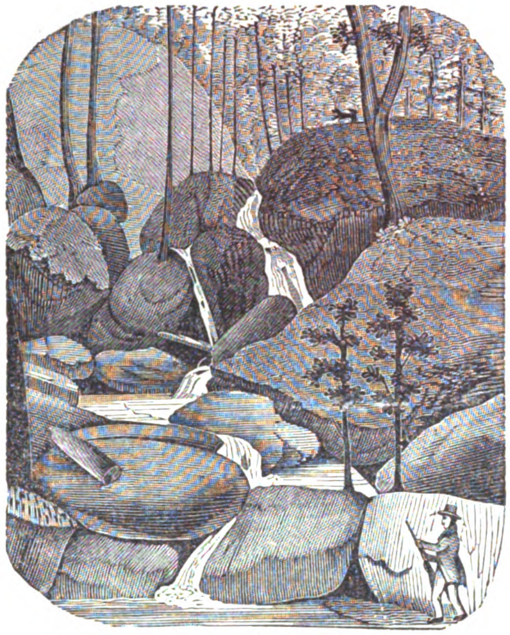
Fig. 40.

*Gorge or Glen: Leyden.—Mrs. Hitchcock, del.*

## *Cascade in Leverett.*

I have recently ascertained the existence of an interesting water fall on northeast side of Mount Toby, in Leverett. The conglomerate rock of that mountain has been subject to powerful abrasion in early times; and being divisible into masses of great thickness, by fissures nearly perpendicular to the horizon, the sides of the mountain frequently present perpendicular walls of solid rock, and sometimes a succession of precipices in the form of vast steps; while the huge fragments that have fallen down, lie scattered along the base. Such is the case at the spot above referred to: where a large brook, called "roaring brook," comes tumbling down by a few successive leaps from the height of 200 or 300 feet. The waters have worn deep chasms in the rocks, and the scenery around is of the wildest and most romantic character. Every thing there—the lofty forests—the overhanging precipices—and the accumulated rocky masses below—remain unmodified by the hand of man, just as the mighty agencies of nature have left them. This will be obvious from Fig. 41.

Fig. 41.



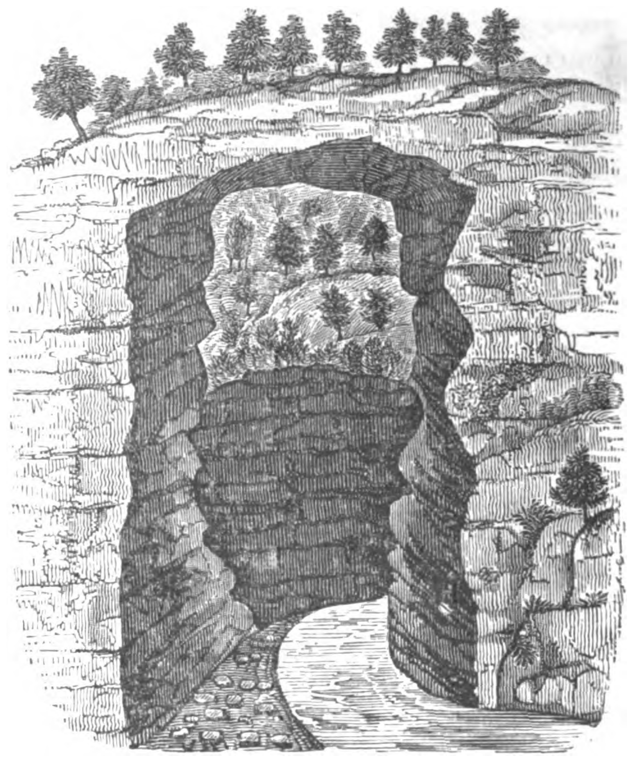
*Cascade in Leverett.—H. J. Van Lennep, del.*

*Cascade, Natural Bridge, and Fissure, on Hudson's Brook.*

The present falls on this rivulet, which runs through the north part of Adams, are of far less interest than the deep chasm which its waters have excavated in the white limestone. This limestone terminates on the south in a high precipice, over which the stream once fell. But it has worn a fissure from 30 to 60 feet deep, and 30 rods long, in this limestone, and left two masses of rock connecting the sides and forming natural bridges: though the upper one is much broken. The lower one is arched, and the stream at present runs 50 feet below it. The medium width of the stream is 15 feet.

Within a few years past, the drill of the quarryman has begun its assaults upon the beautiful white limestone that forms this natural bridge, and the walls of the gorge: and although the intelligent proprietor, whom I met there, partially promised me that he would not mar the beauty of this spot, yet the deep inroads already made upon the upper part of the cliff, are fearfully ominous of the fate of the whole. As I saw it last, the clearing away of some of the rock had brought the natural bridge more distinctly into view. Yet the next advance would take it entirely away. And lest this should be accomplished before a skillful artist shall visit this spot, I thought it better that a sketch should be taken by one not at all accustomed to drawing; than that no memento should be left of this interesting place. Such a sketch is shown in Fig. 42.

Fig. 42.



*Natural Bridge: Adams.*

### *Umpachena Falls.*

The Umpachena is a small stream, rising in the east part of New Marlborough, and passing westerly, unites with the Konkapot; which is a tributary of the Housatonic. Both these streams take their names from those of Indian chiefs, who formerly had possession of that region. Towads the west part of New Marlborough, the Umpachena falls over horizontal strata of quartz rock, by two leaps, to the depth of about 30 feet, the upper cataract being 10 feet. Although there is nothing very striking about these falls, yet there is enough that is peculiar to make them worthy the attention of one who would not pass by any of the interesting natural objects of Berkshire County.

### *Bashapish, or Bash-Pish Falls and Gorge.*

Bashapish or Bash-Pish Falls and Gorge, are upon a small, and so far as I could learn, a nameless stream, passing westward from the center of Mount Washington, through the Taconic range, into New York: near the line of which, they occur. Although the most remarkable and interesting gorge and cascade in Massachusetts, it was only by accident that I learnt their existence, after having been in Mount Washington for sometime. And at that time, I could scarcely find any one in the neighboring towns who had heard of the

spot. I give the name as I heard it pronounced. I shall not undertake to decide upon its etymology: though I perceive that some would derive it from the German, and others from the Indian. I wish the name were better: but it is not so bad as it might be; and it will probably be no easy matter to alter it. Whatever may be thought of the name, however, all I think who visit it, will consider the place itself as highly interesting. But it is quite difficult to convey an adequate idea of it by simple description.

In the first place, it is an enterprise of no small magnitude to get to the spot; especially for ladies: none of whom but the most resolute and vigorous should attempt it, until the roads are improved, or rather *made:* for the main difficulty is, there are no roads that are tolerable for carriages within two miles of the place. A few years since there was a very decent road from Copake in N. York, it being only four miles east of Miller's tavern. But the powerful rains of the summer of 1838, completely ruined it, so that it will be quite as easy to make a new one as to repair the old one. The best course to reach this spot, is to go into Mount Washington from Egremont, as already described in another place, and when you have proceeded as far as the first school house, you will find yourself in the vicinity of a Mr. Schott; at whose house it is better to leave your carriage, and go on foot the remaining two miles. The course lies mostly through the woods, and passes near the thermal spring that has been described in the first part of my report. A little beyond this, and just west of the highest ridge of the mountain, where is some cleared land, a very commanding prospect opens into New York, through the deep valley which is formed by a small stream, bounded on the right and left by the steep slopes of the mountain thus dissevered, and showing ridge beyond ridge, and checkered with woods and cultivated fields, and now and then a sheet of water, until at length the noble Catskill looms up above everything else in the far distant horizon. Fig. 43, will give some idea of this exhilarating prospect. It deserves to be sketched and engraved in a better style.

Fig. 43.

*Distant View of the Catskills from Mt. Washington.—H. J. Van Lennep, del.*

After leaving this spot, you descend a steep hill, nearly 2000 feet, and find yourself on the margin of a small stream, not much more than a rod wide, a little above the point where it begins to plunge and roar down the deep and dark gulf. For a few rods it descends rapidly towards the west, between perpendicular walls of rock, nearly 100 feet high. This rock is talcose slate, whose layers here stand nearly perpendicular, and run north and south, that is, across the course of the current. But ere long the descending stream strikes against a perpendicular mass of rock, which it has not yet been able to force out of its place, and is thereby made to turn almost at right angles to the left, and then to rush down a declivity sloping at an angle of about 80°, in a trough between the strata. This fall cannot be less than 50 or 60 feet; and here the water has performed its greatest wonders. Having for centuries been dashing against the edges of the strata, while at the same time its bed has been sinking, it has worn out a dome shaped cavity to the depth of 194 feet; that is, measuring from the top of the overhanging cliff to the foot of the fall. By creeping along the south side of the stream, where the wall is nearly perpendicular, one can descend to the bottom of the fall; and there he finds himself at the foot of a vast wall of rock, which as he faces the northwest, whither the stream turns its course at the foot of the fall, encloses him on the east, south, and west; and as it rises, it curves outward, so that when he looks up, he sees it at the height of nearly 200 feet, projecting beyond the base as much as 25 feet. A man in such a spot cannot but feel in some measure his impotence: for should only one of these overhanging masses fall, he knows that it would grind him to powder. And when he sees numerous fissures running through the cliff, he cannot feel entirely safe: or rather, it requires several visits to the spot to get his nerves accustomed to the slight danger that exists. The spot where he stands the sun never visits, except by reflection: and he seems to stand at the further extremity of a vast oven, or rather a bathing house. The only opening is down the stream, which continues to descend by successive cascades, until soon it is hidden by the vast blocks of stone, which are there accumulated, and by the overhanging trees. The banks on either hand rise in a very precipitous manner: and through the opening between them, the eyes rests upon a lofty slope, almost naked of trees, at the distance of nearly a mile. I consider the view from this spot through this opening to be very grand and striking; and therefore Fig. 44, though sketched by an unskilful hand, is given. On the right is seen the cascade above described, with the steep hill down which it rushes. On the left hand, is seen the lofty and even overhanging rock that forms the other bank, while between them in the distance, rises the vast slope of a part of the Taconic range and intercepts the view.

Fig 44.

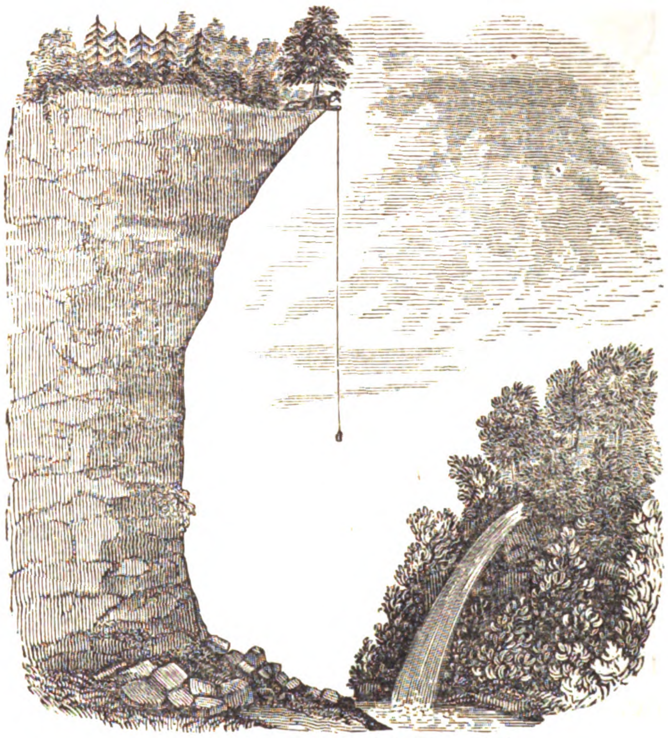
*Bashapish Upper Falls.*

Following the small stream still farther down from this upper fall, we find it rapidly descending by several smaller cascades, which together amount to at least 50 feet, half hidden by huge bowlders, and overhanging trees. At length we arrive at a larger and in fact the principal fall. The water which is divided into two parts by an enormous bowlder poised upon the brink, here falls over a nearly straight and perpendicular precipice of about 60 feet, into a deep basin, two or three rods across. Below these falls, and from the north bank, the view on Plate 14 was taken. This shows beyond and above the falls, the high and overhanging precipice above described, on the south side of the stream; and in fact, the best general view of the whole scenery of this spot may be obtained at this place. But no single view can take in only a small part of that scenery. Below these falls, the water continues to descend and forms several cascades, which in other places would be of interest: but here they are scarcely worth visiting after a person has seen those which I have described.

The object, which I think most persons would regard as the most striking, remains yet to be visited. Let the observer either follow back the rough path he has just trodden on the south side of the stream, or follow by a circuitous route the north bank, until he reaches the spot above the upper falls where he first entered the gorge, and there he will find a steep foot path that will conduct him to the top of the precipice that overhangs the upper falls sketched on Fig, 45. This is mostly covered by bushes: yet in one place he can advance to its very edge, and as the edge projects upwards a little, it

is well adapted to prevent one from falling over: as may be seen on Fig. 45, which will give an idea of the situation of the observer as he looks down into this gulf. On letting down a stone from this spot, with a string attached, I found that it required a length of 194 feet before the water was reached. I have scarcely ever felt such a creeping and shrinking of the nerves and such a disposition to draw back as here. Even though I took hold of bushes with both hands, I could not comfortably keep my eye turned long into the frightful and yawing gulf: for it seemed as if it needed only a stamp of the foot, or perchance only my weight, to cause the rock on which I stood to follow the example of multitudes of the same kind that were strewed at its base. Still I suppose the actual danger to be quite small.

Fig. 45.



*Section at Bashapish Upper Falls.*

Many persons, who visit these falls do not ascend this precipice. But they thus lose more than half the interest of the scene. Others examine the several objects in a reverse order from that which I have described: that is, they go first to the lower falls and follow the stream upwards. But I am inclined to beleive that the effect is most favorable to follow the route which I have described. I have now visited the spot three times, and with scarcely any diminution of interest. But I feel the poverty of description for delineating such scenery. From the top of the highest precipice to the foot of the lower falls, I estimate the perpendicular height to be about 320 feet.

From the account which I have given of Mount Washington, it appears that the town contains an unusual amount of objects of scenographical interest. To examine the most important, two days at least are indispensable: one to ascend Mount Everett, and the other to explore the scenery of Bashapish falls. To one who has a taste for the wild, the romantic, and the grand in nature, those two days will be a season of delightful emotions.

## CAVERNS AND FISSURES.

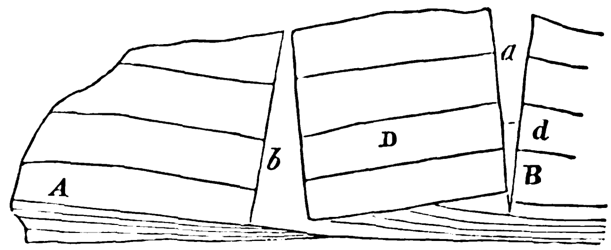
### *Southampton Adit.*

I have alluded in the first part of my Report, to this artificial excavation, 900 feet in length, at the lead mine in Southampton. It is a perforation mostly in solid rock, large enough to admit a boat with several persons; and in this manner might be entered with perfect safety. Being unique in this part of the country, it had become a place of considerable resort by gentlemen and ladies during the summer months. At present the entrance is blocked up; but it is to be hoped that ere long the working of this adit will be resumed, and an opportunity again afforded for so fine a subterranean excursion.

### *Sunderland Cave and Fissure.*

The following section will, I apprehend, render intelligible, not merely the form and situation of this cave and fissure, but also the mode of their production. They occur in a conglomerate rock of the new red sandstone, on the northwest side of Mount Toby, in the north part of Sunderland. The conglomerate strata are several feet thick: and immediately beneath this rock lies a slaty micaceous sandstone, which is very subject to disintegration; as may be seen a little north of the cave, where the conglomerate projects several feet beyond the slate, whose ruins are scattered around. The spot is perhaps 300 or 400 feet above Connecticut river: yet there is the most conclusive proof in all the region around, that water once acted powerfully, and probably for a long period, at various elevations on the sides of this mountain: and not improbably this aqueous agency assisted in undermining the conglomerate rock by wearing away the sandstone.

Fig. 46.




At *A*, and *B*, Fig. 46, the rock is but slightly removed from it original position; but in the space between these points, the slate appears to have been worn away so as to cause the whole conglomerate stratum, which is from 50 to 60 feet thick, and consequently of immense weight, to fall down, producing the fissure *a*, and the cavern *b*. The fissure is nine feet wide at the top, and open to *d*, 40 feet; below which it is filled with rubbish. The cavern is wider than this in some parts, though very irregular in this respect. Its bottom also is rendered quite uneven by the large masses of rock that have tumbled down. In the deepest spot, (56 feet) the rocks are separated to the surface, so as to let in the light from above. The whole length of the cavern is 148 feet. Its general direction is nearly east and west. But towards its eastern part it turns almost at right angles to the left, in consequence of the rock *a*, having been broken in a north and south direction from the mass of the mountain.

Some who visit this spot are disposed to call in the aid of a convulsion like an earthquake to explain the huge fractures there exhibited. But after seeing so many other marks of the powerful action of atmospheric and aqueous agents on this mountain, I cannot but believe the cause I have assigned to be sufficient. The place is well worth visiting by all who have not examined other caverns and fissures extensively.

On the opposite side of Mount Toby, a little south of the cascade that has been described, one or two other caves occur, more irregular but less extensive than this. They have been produced by the enormous masses of the mountain that have been here mixed *pell-mell* together.

### *Caverns in Berkshire.*

These all occur in limestone: and are so similar, that it is hardly necessary to describe them separately. Two exist in the south part of New Marlborough, containing several apartments and some stalactites.

Small caverns exist in Egremont, Alford and West Stockbridge. In Lanesborough, at Baker's quarry, in the northwest part of the town, is a cavern of considerable extent, produced by the erosion of water. It descends northeasterly at an angle of 10° to 15°, and is generally not much larger than is necessary for a man to pass along. Indeed, I found it not easy to penetrate it more than 140 feet; though it is said to have been explored 300 feet. Stalactites occur there of some interest, but not abundant nor handsome. The singular calcareous deposit upon the floor of this cavern, I shall describe in another place. In Adams, a mile south of the north village, is a cavern in limestone of considerable extent. The largest apartment is 30 feet long, 20 feet wide, and 20 feet high. In Williamstown, at the foot of Saddle Mountain, I noticed one or two cases in which streams of some size disappear beneath the surface for several rods in the limestone rock: and here we probably see the manner in which most of the caverns that have been described above were produced.

## *Purgatories.*

I know not what fancied resemblances have applied this whimsical name to several extensive fissures in the rocks of New England. The most remarkable case of this kind is in Sutton, three and a half miles southeast of the congregational meeting house. It is a fissure in gneiss, nearly half a mile long, in most parts partially filled by the masses of rock that have been detached from the walls. The sides are often perpendicular, and sometimes 70 feet high; being separated from each other about 50 feet.

This is an immense chasm: and I confess myself at a loss to explain its origin. It is natural to suppose that its sides have been in some manner separated from one another. But I can conceive of no mode in which this could have been accomplished, but by a force acting beneath: and this would so elevate the strata, that they would dip on both sides *from* the fissure. But I could discover no such dip. The inclination along the fissure corresponds with that which is common in the region around; viz. about 25° N. E. In the vicinity of the fissure, however, the rocks are often exceedingly broken into fragments:* and this circumstance indicates some early subterranean convulsion or the agency or troubled waters: And I am rather inclined to refer these fragments as well as the fissure, to the long continued action of the waves of the sea, when the spot was so situated as to form a shore of moderate

* Visitors of the Sutton Purgatory should recollect that such broken rocks furnish a fine retreat for the Rattlesnake. I met with one among the *debris* of that place. But as he kindly warned me that I was trespassing on his territory, I thought it ungenerous to attack him, and we parted on good terms, mutually willing to be rid of each other's company.

elevation. The case of a purgatory in Newport which I shall describe, will illustrate the mode in which the waves might have produced such effects.

### *In Great Barrington.*

A fissure very similar to that in Sutton, exists in the mountain east of the village of Great Barrington. The best way to reach it, is to pass around the north end of the mountain, and then to go southerly a mile or two, as far as the house of Russell Kilbourn: from whence a walk of three quarters of a mile will lead to the spot. It is an open fissure, about 4 rods wide, with perpendicular walls, which in some places rise to the height of 80 feet. The bottom in most parts is strewed over with loose but not rounded blocks, which were obviously derived from the sides. This detritus frequently fills up the bottom several feet; so that probably the entire depth cannot be much less than 100 feet. Among the loose masses of rock, snow and ice frequently remain through the summer. I found them there in abundance on the 25th, of June in a very sultry day.*

This Purgatory is in gneiss, which a good deal resembles that in Sutton. The strata in Great Barrington are nearly horizontal: and the fissure is nearly straight; but at its western extremity, the sides rather diverge. It runs S. 25° W. and N. 25° E. and extends across the entire ridge of the mountain, at least 80 rods in length. Its bottom cannot be less I think than 800 feet above the bed of the Housatonic. I can mention no explanation of the manner in which it has been produced, except the one suggested in regard to the Sutton Purgatory; and which will I think receive some illustration from certain fissures on the coast of Rhode Island; which I therefore introduce in this place. To persons, however, who are but little familiar with geological changes, probably the explanation which I give of these so peculiar phenomena, will seem no better than wild hypothesis.

### *In Newport, Rhode Island.*

In the southeast part of this town (perhaps it is within the limits of Middleton,) the coarse conglomerate rock contains numerous cross seams, which are parallel to one another, and nearly perpendicular to the horizon. In one spot, in a high rocky bluff, two of these fissures occur not more than six or eight feet asunder; and the waves have succeeded in the course of ages, in wearing away the intervening rock, so as to form a chasm about

* It was amusing to see the effect of the ice at the bottom upon the musquetos, which were very troublesome. But if one wished to escape them, he had only to step down a few feet towards the bottom, where the temperature was so much lower, that they would not follow.

seven rods in length, and 60 or 70 feet deep; the sides being almost exactly perpendicular. This chasm is called Purgatory; and the waves still continue their slow but certain work of destruction.

On the south shore of Newport, a similar fissure occurs in granite. It is, however, much less extensive, not more than twenty feet deep perhaps: and the waves sometimes rush into it with such violence that they are dashed not less than thirty feet into the air. Even granite yields under this everlasting concussion. This spot is called the Spouting Cave.

We have only to suppose the Sutton and Great Barrington Purgatory to have been once similarly situated in respect to the ocean, and we have a cause adequate to its production. And yet, what an immense period must the whole work have demanded!

### *Autumnal Scenery.*

Perhaps no country in the world exhibits in its autumnal scenery, so rich a variety of colors in the foliage of trees, as our own. But it is particularly beautiful in the more mountainous parts of the land. The trees, whose leaves give the liveliest tints, are the maple, the oak, the walnut, and the sumach: while the pine and hemlock retain their deep green: and if these species be fantastically mixed on a mountain's side, they present a splendid drapery, which, though somewhat approaching to the gaudy, is yet extremely interesting. The change generally commences as early as the middle of September, and does not attain its full perfection till after several frosts of considerable severity. The change proceeds undoubtedly from an increased oxygenation of the coloring matter of the leaves; analogous changes being easily produced in the chemical laboratory by the addition of oxygen to certain compounds,* as for example, the *Chameleon Mineral.* This process in the eyes of a chemist does not seem, as I believe it does to most men, a condition of sickness connected with the decay and fall of the leaf. He views it rather as a beautiful illustration of the means which nature possesses to produce variety. True, it is one of the more advanced steps of vegetable life; but does not seem to be disease. Or if any are disposed to consider it such, it ought to be looked upon as nature descending joyfully in her richest dress into her wintery grave, in exulting anticipation of a speedy resurrection.

Although this phenomenon forms an attractive object to the geologist in his wildest excursions among the mountains, at the most delightful season in the whole year for geological research, yet it cannot be regarded as having any connection with geology.

*Annales de Chimie et de Physique, Vol. 38, p. 415.

In my former report, however, I ventured to give a sketch of this scenery which is in a good measure peculiar to this country* but I have not felt justified in repeating this step in the present report; chiefly because the other drawings have been so multiplied. There is less need of a drawing also, because the splendid original is before all our citizens nearly every autumn. The autumnal scenery of other lands may be dispiriting and dreary: not so in ours.

"What is there saddening in the Autumn leaves?
Have they that "green and yellow Melancholy,"
That the sweet poet spake of?—Had he seen
*Our* variegated woods, when first the frost
Turns into beauty all October's charms—
When the dread fever quits us—when the storms
Of the wild Equinox, with all its wet,
Has left the land, as the first deluge left it
With a bright bow of many colors hung
Upon the forest tops—he had not sighed."

*Brainard.*

## *Concluding Remarks.*

Such essentially is the scenery of Massachusetts. I do not flatter myself that I have described, or even found, all the spots interesting enough to deserve a notice in this place. For up to the present time almost, I have continued to discover new places of scenographical interest; and whoever will take the trouble to compare my present with my former reports, will see that such discoveries have been very numerous within a few years past.

And now I earnestly wish that I could communicate to my readers were it but a moiety of the pleasure which I have experienced from an examination of the scenery of the state. But unless I can persuade them to follow my steps, my wish will be vain. But I will suppose that during the summer months, a few gentlemen of taste and intelligence—accompanied by ladies if they please—should wish to exchange the heat of the city, and routine of business for a few weeks of mountain air and alpine scenery. Let them go to Berkshire, and commencing at either extremity, pay a visit to the principal objects which I have described in the preceeding account of our seenery.

* It may not be improper, perhaps, to repeat the remarks made to me by the Baron Roenne, the present worthy Minister of Prussia to this country. Soon after he came here, he saw the drawing of autumnal scenery in my report, and at once pronouced it to be a caricature. But after residing in New England through one autumn, he declared that the drawing fell short of nature. But said he, "I shall be obliged to certify to my friends in Prussia that your drawing is correct, or they will not believe you."

Rev. Justin Perkins, American Missionary in Persia, showed one of these sketches to the Nestorians; who exclaimed; "what a strange country America must be! where they live in wooden houses and the trees are painted!"

In that county alone, they will find enough to occupy them for at least two or three weeks: And so great will they find the variety to be in the scenery of those mountains and vales, that the danger will be, not that they will be uninterested, but that the exhilaration will be too great: And yet this kind of excitement is usually very favorable to health: and I doubt not they would return invigorated for their ordinary pursuits. Or if they have still more leisure, let them wander through the beautiful valley of the Connecticut; and along its tributaries. Then let them visit the Wachusett, and other romantic spots of Worcester county, and pass down the Merrimac: the calm loveliness of whose scenery will most agreeably terminate the excursion. For the varied and unique scenery of our sea coast should be reserved for another excursion; and so contrasted is much of it with that in the interior, that it will not prove the less interesting, because the latter has been previously examined. In short, could our citizens but realize the riches of our scenery, I am sure so many of them would not resort so often to distant spots, beyond our limits, to experience often less gratification than they might find among our own mountains and vales.

# PART III.

# SCIENTIFIC GEOLOGY

OF

# MASSACHUSETTS.

In entering upon the third and most extensive part of my Report, a few preliminary remarks may be necessary.

By employing the term *Scientific Geology*, for this part of the work, I would not convey the impression that the other parts are not in accordance with the priciples of science. For in fact, the results given under Economical Geology, have required quite as much careful scientific investigation as any other part of the work. But as I have endeavored to give those results as much as possible a popular and practical character, I supposed it proper to denominate the third part of the Report, Scientific Geology: because I shall here endeavor to present the facts of our geology in a scientific dress; and to refer the phenomena to their proper causes. In other words, the facts will here be presented in their relation to the science of geology. In doing this, I shall not hesitate to employ the technical terms which are necessary for accurate description, in the sense adopted by the most recent and able writers. To attempt to substitute loose and popular language for that of science, would render the descriptions obscure, and be of little service even to those who are not familiar with the principles of geology: while it would prevent these facts from being of any benefit to the science. Besides, I shall add a fourth part to my Report, in which I shall give as full a view of the fundamental principles of this science as my limits will allow; and that will furnish the reader with the means of understanding all the descriptions and reasonings which I shall introduce. It is fortunate, also, that geology does not abound with technical terms; nor is the number of rocks large.

For a long time geology had to contend with a multitude of unreasonable prejudices, many of which yet operate upon intelligent minds. But so rapid has been its progress for a few years past, so splendid its discoveries, and so profound its reasonings, that in spite of obloquy, it is fast assuming that commanding situation among the sciences to which its dignity and importance entitle it. Many of the ablest philosophers of Europe, have, for several

years past, devoted their energies with untiring interest and great success, to this pursuit; and none but those who do not take the trouble to understand its principles, will now assert that its practical value is not great, or its fundamental principles unsettled. It is still, indeed, making rapid progress: and some of its theories are unsettled: and doubtless some of its principles are destined to receive modification, by new researches and reasonings. But the same is true of every other physical science, even of that which has been the longest cultivated—I mean astronomy.

The gradual passage of rocks into one another will cause many intermediate specimens to be placed in different groups by different observers: because no two men will be likely to draw the dividing line between them in exactly the same place:—or in other words, to say where one of the ingredients predominates and when another does. But in the present case, as I have deposited specimens in the state collection of every variety of rock and mineral described by me, future geologists will be able to know exactly to what rocks my descriptions refer; and if they think me wrong, they can rectify me.

As to the Classification of Rocks, among the principles which I regard as established in the science, one is, the division of rocks into Stratified and Unstratified. This division, therefore, I shall adopt. But instead of stopping here to explain the subdivisions of these classes, I shall introduce a Tabular View of the rocks in Massachusetts, arranged as nearly as possible in the order of their superposition. The first column contains the names of the rocks under which I describe them; the second column, the varieties of each rock observed in Massachusetts, and the third column, a catalogue of minerals found imbedded in each rock. The simple minerals are put down without any attempt at classification; it being thought sufficient to refer them to the rocks in which they are found. The different systems by which the rocks have been arranged by various authors, will be found in the first section of the Fourth Part of my Report.

# A TABULAR VIEW

### OF THE

## ROCKS IN MASSACHUSETTS, WITH THEIR IMBEDDED MINERALS.

## STRATIFIED ROCKS.

| *Names of Rocks.* | *Varieties.* | *Imbedded Minerals.* |
|---|---|---|
| 1. ALLUVIUM. | Alluvium of Rivers.<br>do. of Disintegration.<br>do. of Degradation.<br>do. of Salt Marshes.<br>Dunes.<br>Submarine Forests.<br>Peat.<br>Marl.<br>Remains of Infusoria.<br>Calcareous Breccia.<br>Bog Ore.<br>Manganese. | Bog Ore. Phosphate of Iron.<br>Carbonic Acid.<br>Sulphuretted Hydrogen.<br>Carbonate of Lime.<br>Carbonate of Iron.<br>Muriate of Lime.<br>Sulphate of Lime.<br>Do. of Magnesia.<br>Do. of Iron.<br>Do. of Alumina and Potassa.<br>In Mineral Waters. |
| 2. DILUVIUM. | Clay.<br>Sand.<br>Gravel.<br>Bowlders.<br>Conglomerates. Beds of Hydrate of Iron. | Native Gold. Native Copper. Sulphate of Baryta. Gibbsite. Various Ores of Lead, Iron &c.; and specimens of most of the Minerals mentioned below. |
| 3. TERT. FORMATION. | Eocene. *Plastic Clay;* inclined beds of Clay, Sand, Lignite, and Osseous, and Ferruginous Conglomerates. | Nodular, Columnar, Mamillary, Pisiform, and Ochrey Brown Limonite. Radiated Pyrites. Selenite. Amber. Native Arsenic? |
| 4. NEW RED SANDSTONE. | Conglomerates, Red and Gray.<br>Trap Conglomerate,<br>Sandstone, Red and Gray, Micaceous and Brecciated.<br>Variegated Sandstone.<br>Shale.<br>Bituminous Shale.<br>Bituminous Marlite.<br>Bituminous Limestone.<br>Fetid Limestone. | Native Copper. Green Carbonate Copper. Pyritous Copper. Vitreous Copper. Carbonate of Iron. Sulphuret of Iron. Iron Sand. Galena. Blende. Calcareous Spar. Satin Spar. Sulphate of Baryta. of Strontia. and of Lime. Ankerite. Fluate of Lime. Bituminous Coal. Anthracite. |
| 5. GRAYWACKE. | Conglomerates.<br>Breccias.<br>Quartz Rock.<br>Talcose Aggregate.<br>Classical Graywacke.<br>Graywacke Slate.<br>Amphibolic Aggregate.<br>Varioloid Wacke.<br>Limestone. | Anthracite.<br>Plumbago.<br>Micaceous Oxide of Iron<br>Sulphuret of Iron.<br>Magnetic Oxide of Iron.<br>Epidote. Asbestus,<br>Sulphuret of Copper.<br>Adularia. Quartz,<br>Sulphate of Iron. of Lime. and of Baryta.<br>Fluate of Lime.<br>Calcareous Spar. |
| 6 METAMORPHIC SLATES | Flinty Slate,<br>Conglomerated Quartz Rock.<br>Do. Mica Slate.<br>Do. Talcose Slate.<br>Do. Argillaceous Slate.<br>Mica Slate.<br>Epidotic Rock. | Hornstone.<br>Jasper.<br>Zoisite.<br>Magnetic Oxide Iron.<br>Epidote. |
| 7. ARGILLACEOUS SLATE. | Common.<br>Roof Slate.<br>Argillo-micaceous Slate.<br>Chlorite Slate,<br>Slaty Compact Feldspar and Quartz. | Chiastolite. (Andalusite)<br>Octahedral Iron Ore.<br>Iron Pyrites.<br>Calcareous Spar.<br>Crystalized Quartz. |
| 8. LIMESTONE | Saccharine Limestone.<br>Micaceous do.<br>Fetid do.<br>Bituminous do.<br>White Compact do.<br>Magnesian do.<br>Encrinal do. | Magnetic Oxide, Sulphuret and Hydrate of Iron. White Augite. Mussite, Albite. Tremolite. Graphite. Argentine. Scapolite. Actynolite. Pargasite. Radiated, fibrous and brown Hornblende. Phosphate of Lime. Spinelle. Petalite. Calcareous Spar. Magnesite. Bisilicate of Magnesia. Sphene. Gadolinite. Amianthus. Nephrite. Talc. Sulphuret Molybdenum. Garnet. Allochroite. Almandine. Galena. |
| 9. QUARTZ ROCK | Granular and Hyaline Quartz.<br>Granular porous Quartz.<br>Quartz and Feldspar.<br>Quartz and Mica.<br>Quartz and Talc.<br>Quartzose Breccia.<br>Quartzose Couglomerate. | Brown Hematite.<br>Sulphuret of Iron.<br>Hornblende.<br>Ferruginous Quartz.<br>Chalcedony.<br>Hornstone. Galena. Jasper. |

| *Names of Rocks.* | *Varieties.* | *Imbedded Minerals.* |
|---|---|---|
| 10. MICA SLATE. | Quartz and Mica.<br>Do. and Talc.<br>Do. Mica and Feldspar.<br>Amphibolic and Garnetiferous Mica Slate.<br>Staurotidiferous Mica Slate.<br>Spangled Mica Slate.<br>Argillo-micaceous Slate.<br>Arenaceous Mica Slate.<br>Anthracitous Mica Slate.<br>Plumbaginous Mica Slate.<br>Augite Rock. | Calcareous Spar. Sulphate Alumina and Potassa. Phosphate Lime. Fluate Lime. Amianthus Bucholzite. Crystalized, Fetid, Irised, Rose Red, Yellow, Smoky, Tabular and Agatized Quartz. Hornstone. Pyrolusite. Hydrate Iron. Fibrolite. Kyanite. Staurotide. Andalusite. Schorl. Scapolite. Augite. Garnet. Hornblende. Epidote. Zoisite. Idocrase. Stilbite. Heulandite. Analcime. Chabasie. Anthophyllite. Cummingtonite. Sulphur. Anthracite. Plumbago. Magnetic Oxide Iron. Sulphuret Iron. Native Iron. Arsenical Iron. Arsenical Pyrites. Carbonate Iron. Sulphate Iron. Galena. Blende. Micaceous Oxide Iron. Red Oxide Titanium. White Iron Pyrites. Gigantolite? |
| 11. TALCOSE SLATE. | Schistose Talc.<br>Steatite.<br>Quartz and Talc.<br>Quartz Talc and Mica.<br>Talc Quartz and Hornblende.<br>Talc Feldspar and Quartz. | Blue and Green Carbonate Copper. Magnetic Oxide Iron. Micaceous Oxide Iron. Carbonate Iron. Hydrate Iron. Pyrolusite. Manganese Spar. Bitter Spar. Rhomb Spar. Carbonate Magnesia and Iron. Magnesite. Tremolite. Hepatic Sulphuret of Iron. Asbestus. Hornblende. Actynolite. Sulphuret Molybdenum. Red Oxide Titanium. |
| 12. SERPENTINE. | Compact Serpentine.<br>Serpentine and Talc.<br>Do. Do. and Schiller Spar.<br>Do. and Carbonate Lime. | Amianthus. Asbestus. Picrosmine. Chromite Iron. Scapolite? Anthophyllite. Kerolite. Actynolite. Chalcedony. Drusy Quartz. Massive Garnet. Steatite. Chlorite. Picrolite Schiller Spar. |
| 13. HORNBLENDE SLATE. | Hornblende Crystalline.<br>Do. and Feldspar.<br>Do. and Quartz.<br>Do. Feldspar and Mica.<br>Do. and Epidote.<br>Do. and Chlorite.<br>Actynolite Slate. | Red Oxide Titanium,<br>Sphene. Feldspar Crystallized,<br>Epidote.<br>Garnet. |
| 14. GNEISS. | Granitic.<br>Schistose.<br>Laminar.<br>Porphyritic.<br>Amphibolic.<br>Epidotic.<br>Augitic.<br>Anthophyllitic.<br>Arenaceous.<br>Talcose. | Graphite. Epidote. Sulphuret of Molybdenum. Adularia. Albite. Garnet. Pyrope. Schorl. Adularia. Sphene. Epidote. Anthophyllite. Hornblende. Magnetic Oxide Iron. Iron Pyrites. Arsenical Pyrites. Red Oxide Titanium. Gray Copper. Crystalized Quartz. Amethyst. Chalcedony. Iolite. Green Feldspar. Steatite. Serpentine. Mesotype? and Lincolnite, (Vt.) Prehnite. Native Alum. Allanite. Fibrolite. |

## UNSTRATIFIED ROCKS.

| *Names of Rocks.* | *Varieties.* | *Imbedded Minerals.* |
|---|---|---|
| 15. GREENSTONE. | Common. Hornblende and Feldspar,<br>Columnar.<br>Compact.<br>Indurated Clay.<br>Hornblende, Augite? and Feldspar.<br>Porphyritic.<br>Amygdaloidal.<br>Concreted.<br>Tufaceous. | Crystalized Quartz. Tabular do. Amethyst. Chalcedony. Carnelian. Cacholong. Hornstone. Epidote. Chlorite. Asbestus. Prehnite. Chabasie. Mesotype. Stillite. Lincolnite. Calcareous Spar. Datholite. Chlorophœite. Augite. Laumonite. Sulphate Baryta. Green Carbonate Copper. Pyritous Copper. Muriate Copper. Sulphuret Iron. Magnetic Oxide Iron. Selenite. |
| 16. PORPHYRY. | Compact Feldspar.<br>Antique Porphyry.<br>Two or more Crystalline Minerals imbedded.<br>Brecciated Porphyry. | Specular Oxide of Iron, |
| 17. SIENITE. | Feldspar and Hornblende.<br>Feldspar, Quartz and Hornblende.<br>Feldspar, Hornblende, Quartz and Mica.<br>Porphyritic Sienite.<br>Conglomerated Sienite.<br>Augitic Sienite. | Epidote. Green, Brown and Striped Feldspar. Hypersthene. Amethyst. Zircon. Fluate Lime. Crystalized Quartz. Arragonite. Chabasie. Laumonite. Prehnite. Sulphate Baryta. Sulphuret of Lead. Blende. Pyritous Copper. Specular Oxide of Iron. Red Oxide Titanium. |
| 18. GRANITE. | Common. Quartz, Feldspar and Mica.<br>Pseudomorphous.<br>Porphyritic.<br>Graphic. | Fluate Lime. Phosphate Lime. Calcareous Spar. Brown Spar. Argentine. Crystalized, Limpid, Smoky and Fetid quartz. Amethyst Rose Red Quartz. Sulphuret Baryta. Spodumene. Lepidolite. Tourmaline. Green, Blue, (Indicolite) and Red (Rubellite,) Feldspar, Green, Adularia. Albite. Beryl. Garnet. Iolite. Hornblende. Talc. Yellow Pyritous Copper. Blue and Green Carbonate and Muriate Copper. Sulphuret Iron. Specular Oxide of Iron. Vitreous Black Oxide of Iron. Sulphuret, Carbonate, Sulphate, Phosphate, Murio-Carbonate, and Molybdate of Lead. Phosphate Manganese? Oxide of Tin. Sulphuret Zinc. Sulphuret Molybdenum. Crichtonite. Phenakite? Microlite. Rutile. Pyrolusite. Triplite. Variegated Copper. Columbite |

In describing the various rocks in the State, I shall as far as possible, follow a uniform order, giving first the lithological characters; next the topography of the formation; next the dip, direction, &c. of the strata: next an account of the organic remains; next of the mineral contents; and finally, add some theoretical considerations. In many instances, however, this order cannot be observed; and in others, some of the above particulars will need no notice.

A few words more may be necessary in explanation of the Geological Map. I have striven to reduce it to such simplicity, that its plan and arrangement will be obvious by mere inspection. Some things about it, however, may need elucidation. To avoid confusion and mistake, I have employed but six colors; which, with the exception perhaps of the blue, are so strongly marked, that they can readily be distinguished by candle light. These colors mark off the rocks of the State into what may be regarded as distinct groups: the members of each group, with the exception of the fourth, being so nearly related, that they might even be regarded, in most cases, as belonging to the same formation. The first group, however, embracing all the unstratified rocks, would, include more than one formation, if that term can embrace only the rocks produced during one geological period. The second group embraces only gneiss, and those rocks which are so intimately associated with it, that they constitute but a single formation. The third group comprehends mica slate and those rocks that are so closely connected with it, as to show great similarity in the causes that produced them; although perhaps not all of them were formed during the same period. The fourth group is miscellaneous, including rocks that have no necessary connection or resemblance. The fifth group includes all the consolidated rocks resulting from sediment: although obviously belonging to at least three distinct formations. The sixth group takes in all the unconsolidated beds above the chalk, or its equivalent in this country, the ferruginous sand formation.

The tablets attached to the Map will show the particular marks by which the members of the different groups are distinguished from one another: And to afford still farther means for accomplishing the same object, and preventing mistakes, I have placed a figure on each tablet, which corresponds with the same figure placed upon the map in every place occupied by that particular rock; so that even if in any case the painter has applied a wrong color, these figures will afford the means of detecting the mistake.

## STRATIFIED ROCKS.

The uppermost portion of this division of the crust of the globe, consists for the most part of unconsolidated layers of sand, clay, and gravel. The lower portion embraces all those solid rocks that are divided into parallel and continuous masses. The stratified rocks occupy in every country by far the largest proportion of the surface.

### *Alluvium.*

It is well know that a number of causes are daily operating to modify the surface of the globe. In some instances new and solid rocks are gradually forming; in others, and those far the most numerous cases, the rock strata are wearing away, and the fragments, carried by water to the lowest spots, are deposited in the form of sand, gravel, clay, and loam. But all such deposits, whether consolidated or not, are denominated alluvium: excepting only the products of volcanoes.

## Alluvium of Rivers.

The deposits produced by the overflowing of rivers, are the most common and familiar examples of this stratum. They will, of course, consist of that heterogeneous mixture which a swollen and agitated stream sweeps along. When first the river issues from the mountains and begins to spread over the plains, coarse gravel and sand, and not unfrequently large bowlders, will be deposited. The finer materials, and most of the vegetable and animal substances, being lighter, will float on farther before subsiding. So that the portion of an alluvial tract which is nearest the mouth of the stream, will generally be most valuable in an agricultural point of view, being made up of the finest and richest loam.

It is quite obvious that the power of rivers in depositing alluvium must be lessened by every successive inundation; since the more elevated the banks, the less frequently will the stream rise above them; and the less the amount of water thrown over the meadows. In some places along the Connecticut and its tributaries, the banks have already attained such an elevation, that it is only at long intervals that the floods rise high enough to surmount them; and yet they are obviously the result of alluvial deposition.

The Connecticut and its tributaries, the Deerfield and the Westfield, furnish the only examples of river alluvium of much extent and importance in the State. Some fine meadows of this description, however, occur on the Housatonic, in Stockbridge, Great Barrington and Sheffield. Indeed, every river in the State, and every brook, present limited tracts of this stratum. But only those along the Connecticut and Housatonic were thought deserving of a place on the Map. In some instances the deposition of the Connecticut, the Deerfield, and the Westfield, is 15 or 20 feet thick. Logs, leaves, walnuts, butternuts &c. are frequently imbedded at that depth, and but slightly changed. Relics of this kind, though of but little importance to the geologists of the present age, may be viewed with great interest in future times, when this alluvium shall have become consolidated and other formations shall be imposed upon it.

The alluvial basin of Deerfield river, in Deerfield, is perhaps the most remarkable example of this formation in the State. It is shut in on all sides by high land, and the river is obliged to force its way to the Connecticut through a narrow gorge in a high ridge of greenstone; and its direction where it empties, is almost opposite to the course of the Connecticut. The Deerfield, being a mountain torrent, and of less extent, is raised several hours earlier than the Connecticut after a rain. It even begins to subside before the latter has risen much. But as the Connecticut swells, it throws back the waters of the Deerfield over the broad basin among the mountains, and sometimes retains it there for three or four days, or even a week, until the very finest sediment is deposited. The consequence is, a rapid growth of alluvium, and great fertility of soil.

It is interesting to observe in Deerfield Meadows the numerous changes in the bed of the river, that have taken place at no very remote period; though none of much importance since the settlement of the place by the whites. A map of these changes might be instructive as illustrating the operation of existing geological agencies. But I did not judge it expedient to construct one, since so many other cases of more importance will require drawings. I remark, however, that as the banks of this river are easily worn away, constant changes are taking place with much rapidity by the action of the stream, so that it must be a fine place for studying fluviatile dynamics.

Patches of river alluvium are represented on the Map in Stockbridge, Sheffield, Great Barrington, Longmeadow, Springfield, West Springfield, Northampton, Hadley, Hatfield, Whately, Deerfield and Northfield.

The interesting researches of Dr. Dana upon the alluvium of Merrimac river have already been given in the first part of my report (p. 113,) because of its practical bearings. But their importance in a scientific point of view, will, I trust, be duly appreciated. In the whole records of geology, I have not met with any experiments on this subject, more accurate and satisfactory.

### *Coast Alluvium.*

This sort of deposition is of two kinds. The first is produced by tides and currents in the ocean, which frequently transport large quantities of soil from one place to another, and cause it to accumulate in those situations where their force abates, or is destroyed. In the southeastern part of the State, such cases are numerous: and I have regarded the sandy accumulations of this kind in Provincetown; opposite Chatham and Harwick; on the north shore of Barnstable; and in several places along the northwest coast of Nantucket, as of sufficient extent to deserve a notice upon the Map. Deposits of this kind on a smaller scale are very common in the southeast part of the State.

### *Salt Marsh Alluvium.*

Salt marsh alluvium results from the joint action of two, and sometimes three causes: 1. from the decay of salt marsh plants; 2. from the silt brought over the marsh by the tides; and 3. from the alluvial soil brought down by streams, when these happen to empty through those marshes. The marshes in the vicinity of Boston consist chiefly of a clayey loam, with vegetables more or less decayed, forming in fact an imperfect deposit of peat. The depth of the peculiar pulpy soil of these marshes is rarely more than 6 or 8 feet. In the southeastern part of the State, the salt marshes are much more sandy. In fact their character depends very much upon the nature of the soil on the coast, since this is carried by the sea into the marshes and deposited. Though salt marshes are numerous along the coast, this kind of alluvium is marked on the map in only two places, viz. in Charlestown and Chelsea.

### *Submarine Forests.*

Though these have not hitherto been noticed in this country, I am inclined to believe that they are not uncommon in the southeast part of the State, and probably all along the Atlantic coast. They consist of the remains of ancient forests, now submerged a few feet below the sea, though sometimes laid bare at low water. The vegetables found in them are generally such as grow in low land; and, indeed, peat not unfrequently occurs. This is the case in the harbor of Nantucket, as I am informed by Lt. Jonathan Prescott,

of the United States army. This gentleman, while superintending the dredging of that harbor, found portions of cedar, maple, oak, and beach trees, some of them in an erect position and accompanied by peat of an imperfect character. All the wood, except the cedar, (*Cupressus thuyoides,*) which was nearly as sound as ever, was very much decayed. These relics were buried by four feet of sand, and were about eight feet below low water mark.

Another submarine forest exists at Holme's Hole, on Martha's Vineyard. It is on the west side of the harbor, and was described by the pilot as having the appearance of a marsh at low water. Stumps have been found there in considerable quantity; of the cedar at least.

Near the southwest extremity of the Vineyard, on the north shore, I was informed that another forest of a similar description may be seen. On the north side of Cape Cod, also, opposite Yarmouth, cedar stumps may be found (as I was informed by the Captain of the Falmouth packet,) extending more than three miles into Barnstable Bay. And Mr. Henry Wilder, of Lancaster, who first directed my attention to this subject, says that the same thing occurs in the bay of Provincetown, on the side opposite the village. Farther inquires will no doubt bring to light many other instances of a similar character: for my opportunities of observation on this subject have been but few.

Geologists are not a little perplexed, satisfactorily to account for submarine forests. Some of them, it has been thought, might have resulted from the breaking of the barrier of a peat swamp by the ocean; whereby it was drained and the soil rendered more compact so as to subside below the level of the ocean. But in general it has been supposed that these forests have subsided in consequence of earthquakes or other internal movements of the earth. Yet the evidence of such subsidence is in most cases very equivocal. I suspect that observers have too readily admitted that these forests occupy the very spot where they grew, and that more careful examination would show that they have been drifted from a higher level to their present condition. A curious example of such transfer I have described in the first Part of the Journal of the Boston Natural History Society, p. 338, in giving an account of the geology around Portland in Maine. I cannot but think that a similar explanation will apply to very many cases of submarine forests.

### *Peat.*

Various causes are in operation to produce an accumulation of mud upon the bottoms of ponds, lakes, estuaries, &c. In this mud various aquatic plants will take root, and by their decay will swell the deposit. At length the pulpy mass nearly reaches the surface, when sphagneous and other mosses take root in it, along with numerous other plants, and by their gradual decomposition, the pond or the lake becomes converted, in the course of ages, into a

swamp or marsh. On digging into it, the bottom will be found to consist, near the surface, of interlaced vegetable fibres and roots, with only a small portion of earth; farther down the vegetable matter will be found more decayed and compact, until at length, in many instances, perfect compact peat, with occasional layers of mud, will be discovered.

This is the simple and summary account of the origin of the different varieties of peat. And since the process is daily progressing, it is properly an alluvial formation. According to this statement, almost any vegetable matters, that have remained for some time beneath the surface of the soil, may be called peat; and it may even be produced beneath the sea by marine plants, such as the *Zostera marina*. It is only within certain limits of moisture and temperature, however, that proper peat can be produced; and hence in the torrid zone, the decomposition is so rapid and perfect, that peat is rarely found. Hence, too, in northern latitudes, the most elevated swamps are the most favorable spots for its production: that is, for abstracting the oxygen and hydrogen of the vegetable and leaving the carbon to predominate.

Numerous as are the deposits of peat in Massachusetts, very little need be said concerning it. All the varieties noticed by authors—the marsh—the lake—the forest—the maritime and the transported peat—are found here. Indeed, according to the definition that has been given of this substance, it is perfectly obvious that not a town in the State can be named where more or less of it does not exist. The eastern section, however, is certainly best stored with those varieties that may be employed for fuel. And it is an unexpected fact, that the southeastern parts of the State, which abound with sand, contain also a large amount of peat. According to a survey by Lt. Prescott, the island of Nantucket and the small adjacent islands of Thuckanuck, Muskegut, and Gravel, contain 30,590 acres; of which, 1050 are fresh ponds, and 650 are peat swamps* the beds being from 1 to 14 feet thick, and generally of good quality. This must afford an inexhaustible supply of fuel for the inhabitants; and yet I was surprised to learn, that although the price of fuel is very high there, peat is not much employed. This perhaps results from the habit of bringing almost every article used on the island from abroad; or more probably from the general thrift and comfortable circumstances of the inhabitants, which enable them to employ the kind of fuel that is most pleasant; and who is there that would not prefer wood to peat.

The process by which peat is produced, must generally be every year less prolific in its results in this country. For many swamps are already so much filled as to raise the plants on their surface too high to receive the requisite moisture. And besides, the trees and shrubs are cleared away from many, and their surfaces converted into fields for producing grass. Some very fine mowing lots of this description may be seen a little west of the village in Nantucket: and over the whole surface of that island, scarcely a tree or shrub is now to be seen, so that here the formation of peat has probably in a good measure ceased. The peat swamps there (as they now are in many parts of the southeastern extremity of the State) were probably once covered with the white cedar.

According to the Messrs. Danas, trunks of trees, generally of some species of pine, occur in peat, several feet below the surface in the marshes of Charles river.

* 985 acres, according to Mr. Jared Coffin. See First Part of this Report, p. 145.

## *Marl.*

I have given so full an account of the marl beds of Berkshire County in the first part of this report, that little need be added here. The shells which are found in these beds are *Planorbis parvus, bicarinatus, and trivolvis ; Lymnæa heterostropha and catascopium*, with a species of *Cyclas*, probably nondescript (Nos. 12 to 16.) It will be seen that these are identical with living species. The quantity of these shells varies in different beds exceedingly. In some places scarcely any are present: in others they are quite numerous. From such facts, and others which I have observed, I have been led to infer that the common impression that these marls have resulted almost entirely from the decomposition of these shells, cannot be correct; and that a large part of them is deposited from water. The marl is usually found beneath a deposit of peat. I suppose this explained by a statement already made ; that until a pond is nearly filled up, sphagneous mosses will not begin to grow upon its surface. But when these do begin to vegetate, the water becomes so shallow, that very little lime is brought into it, and of course the peat takes the place of the marl.

## *Deposits of the Remains of Infusoria. (Siliceous Marl.)*

In those parts of the state where no limestone marl has been found beneath the beds of peat, a siliceous deposit of a peculiar character often occurs, in the same situation, greatly resembling marl. It is distinguished from marl, however, by not effervescing with acids ; and from fine sand, by becoming light and spongy when dried. In the first part of my of Report, however, I have already described this curious substance (p. 99,) with its principal localities, so far as they are known to me ; and the thickness of its beds. Until recently the nature and origin of this deposit were entirely unknown. But on seeing the paper of Prof. Bailey in the American Journal of Science, (Vol. 35,) on Fossil Infusoria, I was led to examine my specimens microscopically; and discovered at once that they were composed almost entirely of the shells or skeletons of animalculæ: that is, of minute animals inhabiting the water, that are enclosed in a very delicate siliceous envelope, which remains almost unchanged when the animal dies and falls to the bottom. The reason why this deposit is usually covered with peat, or mud, is the same as has just been assigned for the analogous situation of marl.

How very singular, that animals so very minute should perform so important an office in the geological changes that are taking place on the globe! Here we have deposits several feet thick, extending over hundreds of acres, made up entirely of the remains of animals of which hundreds of thousands are requisite to form a single cubic inch! We have long been accustomed

to admire the process by which the minute Polyparia rear the extensive structures known by the name of Coral Reefs, stretching over hundreds of leagues in tropical seas. But now we find that within our own observation, we may see effects no less marvelous, produced by animals of a still more diminutive size—too small, indeed, to be discovered by the naked eye. In the fourth part of my report, I shall describe facts still more astonishing on this subject; brought to light by the labors of Ehrenberg. Truly, imagination can hardly keep pace with the discoveries of modern science!

I was very anxious to obtain the opinion of Professor Bailey upon the specimens of siliceous marl from the localities in Massachusetts; and accordingly transmitted specimens to him, with the request that he would furnish as full an account of them as he thought proper for this Report. The result is, that he has sent me the following very valuable communication, which I am happy to substitute for my own remarks. Even if I had the means and the leisure for studying these curious remains, I should prefer to have it done by one who first called the attention of geologists in this country to this subject, and who has cultivated it with so much diligence and success.

*West Point, Sept.* 19*th.* 1840.

DEAR SIR:—My absence from West Point during the past summer, must be my apology to you for not sooner answering your letter of the 22d. June, which accompanied some fine specimens of fossil infusoria, and in which you request me to furnish something concerning them for the final Report on the Geology of Massachusetts.

I have paid considerable attention to the recent and fossil Infusoria of the United States, but have pursued this study under the disadvantage of not possessing Ehrenberg's splendid work, which is justly considered as the standard in this interesting department of natural history. My knowledge of the labors of others is consequently very imperfect, and I am often unable to identify our species for want of figures to refer to. I have, however, derived much information from the "*Recherches sur l'organization des Animaux Infusoires*, par Chr. G. Ehrenberg," which is appended to the excellent "*Traite pratique du Microscope*, par L. Mandl," and from this work I have translated the generic and specific characters of the species of Infusoria described in the subsequent part of this letter.

As I hope soon to publish in Silliman's Journal some occount of the Fossil Infusoria of the United States, and their allied recent species, I must refer to that article for more ample details than I have now time to give. I shall content myself, for the present, with a few remarks which appear likely to be of interest with regard to the fossil Infusoria of Massachusetts. If you think these remarks of sufficient value to find a place in your final Report, you are at liberty to make that use of them.

## *Remarks on the Siliceous Infusoria.*

*1st. Their animal nature.* As the living species may be found in almost every lake, pond, stream, or bog, any one who has a good microscope, can easily convince himself that they are animals. I have frequently shown them to various scientific friends, and not one, who has ever witnessed their active and voluntary motions, has ever doubted that they were true animals.

*2d. Their extensive distribution.* I have observed the living species in various places from

Rhode Island to the Ouisconsin Territory and south to Virginia, and they doubtless occur all over our continent; and as the living species are so extensively distributed, I have little doubt that the fossil species are equally so, although all the localities *yet discovered* in this country are in primitive regions. As we have numerous very beautiful marine species now living on our sea coast, it is highly probable that our tertiary formations when properly examined will yield some intercsting fossil specimens.

3d. *Characters of the family of Bacillariæ.* The greater part of the Infusoria whose siliceous coverings or carapaces," are found in a fossil state, belong to the family of *Bacillariæ*, which is thus characterized by Ehrenberg.

BACCILLARIÆ.

"Polygastric (distinctly or probably,) without intestinal canal; appendices (distinctly or probably variable,) undivided, body multiform: carapace, often prismatic and siliceous with one or several openings, often having the form of articulated polypidoms in consequence of imperfect (longitudinal) spontaneous division." *Mandl et Ehrenberg, l. c. p.* 241. There are about 35 genera.

## *Characters of the most interesting Genera and Species occurring Fossil in Massachusetts.*

### *Navicula.*

The species of this genus are among the most common as well as most beautiful of the family. The genus is thus characterized.

"Free, isolated or binary; carapace simple, bivalve or multivalve, (sileceous,) prismatic, having six openings, never united in form of a chain by perfect spontaneous division." *Mandl et Ehrenberg l. c. p.* 259."

*Navicula viridis.* (Plate 20, figs. 1. 2.) Ridged, ("rayee") carapace straight, linear, truncated laterally at each end, rounded on the ventral side, fifteen internal ridges, ("raies") (cells) in 1-100 of a line. Length 1-96 to 1-6 of a line," *l. c. p.* 265.

This very beautiful species occurs in most of the specimens of Fossil Infusoria both in Europe and this country. It is very common in the living state. Ehrenberg gives in his small work entitled "Die fossilen Infusorien und die lebendige Damanerde," a figure which I have copied (See fig. 3,) in which he represents internal stomachs and external organs of motion.

*Navicula* ——— ? figs. 4. 5. Another common species is easily recognised by two groves crossing each other at right angles on the lateral faces of the carapace. I am unable to determine its specific name. It is common both in a recent and fossil state.

*Navicula* (Surirella) nov. sp. ? (figs. 6. 7 8.) This equisitely beautiful form appears to belong to the sub-genus Surirella, but is unlike any thing I have seen among fossil Infusoria from Europe. I have found it abundant in a living state in various places near West Point, also in Culpeper County Virginia. Its winged angles with large and distinct markings readily distinguish it from any thing else. It occurs in a fossil state in Bridgewater, Mass.

### *Cocconema.*

"Carapace simple, bivalve or multivalve (siliceous) fixed by one end, pediculate "longer than broad, pedicle in the direction of the axis of the body, (pediculate Naviculæ )

The species are often found separated from the pedicle and moving about freely.

*Cocconema* —— ? figs. 9.10. This species is very common both in a recent and fossil state. Fig. 10 *a*, is probably another species, which occurs fossil at Manchester, Mass.

## *Eunotia.*

" Free, isolated or binary, carapace simple, bivalve or multivalve (siliceous) prismatic, four openings on the same side, two at each end : flattened on the ventral side, convex and often serrate on the back, never having the form of a chain by perfect spontaneous division." *l. c. p.* 268.

*Eunotia arcus* (figs. 11. 12.?) Ridged, carapace semi-lanceolate, elongated, wider than high, two terminal knobs, urcuate, 11 ridges in 1-100 of a line. The species represented by figs. 11, 12, appears to agree pretty well with this description.

*Eunotia diodon, triadon, tetradon et pentodon,* (Figs. 13 to 17?) Ehrenberg describes by these names several species of Eunotia differing chiefly (as I think,) in the number of toothlike elevations on the back. I believe this to be an uncertain character; and I feel pretty sure that the figures above referred to belong to different states of the same species.

## *Gomphonema.*

" Carapace simple (siliceous) straight, wedge form ; fixed on a distinct filiform pedicle, branching dichotomously by spontaneous division." *l. c. p.* 284.

This genus is easily recognised by the pediculate *wedge* form frustules. The animalcules are often seen detached from their foot stalk, and then move about freely.

Two species are represented in figures 18 and 19. The small figure (18a) shows the branching filaments which support the siliceous frustules.

## *Fragillaria.*

" Free, carapace simple, bivalve or multivalve, siliceous, prismatic, formed of continuous chains (resembling fragile ribbands) by imperfect division of the carapace and body." *l. c. p.* 276.

*Fragillaria pectinalis,* (fig. 20, 21. This very common species is often found in the fossil slate in Massachusetts; it appears to be the F. Pectinalis of English Algologists, but differs from Ehrenberg's character of being " swollen and lanceolate on the lateral side, 8 ridges in 1–100th of a line."

## *Gaillonella.*

" Free, carrpace simple, bivalve (siliceous) forms cylindrical, globular or discoid, having the form of a chain by imperfect spontaneous division."

*Gailonella distans,* (fig. 22.) Corpuscles cylindrical, short, truncate and flattened on two sides, smooth, two pierced furrows (" sillons,") always separate in the middle. 1—576th to 1—72d line, usually about 1—28th of a line." *l. c. pp.* 256, 258.

This species in the fossil state constitutes a large portion of the polishing slate of Bilin and Cassel, the fossil farina of Santa Fiora and Kymmene Gard.

It is common in the recent and fossil state in Massachusetts. The specimens of Fossil Infusoria from Manchester are almost entirely composed of it.

To this genus belongs G. ferruginea, a figure of which is given in Lyell's Geology, (p. 39.) It is considered by Ehrenberg as contributing to the formation of bog iron ore. It is probably common throughout the United States, as I have seen it in Rhode Island, New York, Ousconsin, and Virginia.

Many other species of Infusoria occur in the fossil state in Massachusetts, but I must refer for further information with regard to them to the memoir above mentioned which I hope soon to complete.

## *Siliceous Organic Bodies not derived from Infusoria.*

*Spongilla lacustris*, (figs. 22, 23, 24 and 25.) Almost every specimen of fossil Infusoria which I have examined, contained spiculæ of the fresh water sponge. I have frequently examined this singular production while living, and have satisfied myself that the spiculæ (figs. 22, 23, 24 and 25,) so common in the fossil state are derived from this supposed animal body. A very large portion of its mass is made up of these siliceous spiculæ entangled and crowded together in vast numbers.

*Amphidiscus rotula*, Ehr. (fig. 26.) This name has been given by Ehrenberg to small siliceous bodies which he aptly compares to little thread spools. Their nature is unknown; but Ehrenberg conjectures that they are internal portions of a Spongilla or Tethya. They were first detected by Ehrenberg in specimens of fossil infusoria from West Point. He afterwards found them in specimens from the banks of the Amazon. I have found them in the peat earth of West Point, and in specimens from near Boston, also particularly abundant among the fossil infusoria of Wrentham, Mass.

## *Examination of Fossil Infusoria from Localities in Massachusetts.*

It will perhaps be unnecessary to state in detail the species found in each of the specimens you sent me from localities in Wrentham, Bridgewater, Spencer, &c. &c. It will I think be sufficient to state that most of them contain the same species, among the most abundant of which are Navicula viridis (figs. 1, 2.) Navicula ?——— (figs. 4, 5.) Cocconema, ——— (figs. 9, 10.) Eunotia, several species; Synedra; Fragillaria pectinalis, (figs. 20, 21.) Gaillonella distans, (fig. 22.) and occasional frustules of Gomphonema, and Bacillaria, together with siliceous spiculæ of Spongilla. The most interesting specimens are the following.

No. 1, from *Wrentham*. This is very pure and white, and in addition to numerous common species, it contains the *Amphidiscus voluta* in greater abundance than any specimen I have seen from other localities. There are also present in it some very minute spheres (fig. 27,) and tear shaped bodies (fig. 28,) belonging to species of Infusoria which I have not yet satisfactorily determined. It also contains a number of *siliceous* bodies (see fig. 29,) which resemble the prickles on the cuticle of certain aquatic grasses, but I am not certain that this is their origin.

No. 2, from *Manchester*. This is a perfect specimen of *fossil farina (Bergmehl.)* It is chiefly composed of frustules of *Gaillonella distans*, which are so minute as to form an impalpable powder, among which are scattered a few individuals of Navicula viridis, a Cocconema, fig. 10a, a species of Eunotia, (figs. 13 to 17,) with a variable number of tooth like projections at the back. There is also present in the specimen two species of small Naviculæ, (figs. 30, 31,) which I have not noticed elsewhere. I also noticed in it a small number of granules of the *pollen of some Coniferous plant*.

No. 3, from *Bridgewater*. This is very impure, containing a large portion of sand. It is however of interest as it affords the only fossil specimens I have yet seen of the beautiful Navicula ? (figs. 6, 7.) This occurs however but rarely and mostly in fragments. The most abundant species in this specimen is *Navicula viridis*.

No. 4, from *Spencer*. This is a very white, compact specimen, resembling a lump of Carbonate of Magnesia. The species it contains are only the most common ones, such as Navicula viridis, Cocconema, (fig. 9, 10,) frustules of Gaillonella distans, &c.

No. 5, from *Andover*. This is lead colored, contains some sand with numerous common species of Infusoria, a large number of the minute spheres and tear shaped bodies, figs. 27, 28, and

I noticed also a Pyxidicula, a fragment of an Amphidiscus with the stem unusually long, and some irregular linear bodies which perhaps were derived from the siliceous cuticle of some aquatic grass.

Besides the above, I have examined the specimens you sent me from Sturbridge, as well as specimens from near Worcester and Boston, sent to me by O. Mason, Esq. These all contain Infusoria, but I noticed none of peculiar interest except Amphidiscus voluta in the Boston specimen.

The figures illustrating the above were all drawn to the scale annexed, which represents 10—100ths of a *millimetre*, as they appeared with the same combination of lenses, camera lucida-eye piece, &c. as was used in making the figures. This scale then will serve to show the absolute dimensions of any of the objects above represented, and it is easy by means of it to determine the magnifying power employed.

The microscope I use is an excellent achromatic one, made by Charles Chevalier. The highest power was not used in drawing the above figures, as it would have made them uselessly large.

I think you can add greatly to the interest of the above hasty sketch, by giving an account of the various localities from which the specimens were collected.

With much respect, I remain,

Your Obt Servant,

J. W. BAILEY.

Prof. Hitchcock.
*Geologist, for Mass.*

*Explanation of Figs.* 1, 2, *and* 3.

Fig. 1. Side View of Navicula viridis. Fossil, from Wrentham.

Fig. 2. Ventral side of some specimens.

Fig. 3. Ehrenberg's representation of the living animal. He gives the following explanation of the figure. "A living specimen from Berlin, in which by the injection of indigo are plainly to be recognized, the stomach *v*, the two great spherical sexual glands *ss*, and the plate form extensions of the green ovarium, *o* mouth opening, *o* sexual opening: *a a a a*, four movement openings *p*, *p*, &c. the pediform organs of motion. The visible currents on the body both creeping and at rest are denoted by arrows." Fig. 3, ventral side.

Unfortunately the engraver of Ehrenberg's figure neglected to place the necessary letters of reference: I have ventured to supply the omission as far as I could with certainty.

## *Recent Calcareous Breccia.*

I have discovered but few examples of the recent formation of conglomerates or breccias in Massachusetts. But No. 1552 in the State Collection, which was presented to me by Charles B. Boynton Esq. of West Stockbridge, is a curious example of this sort. In the marble works under his care in that town, the fragments broken off were thrown into a small stream that carried the machinery: and 17 years afterwards, they were found converted into this breccia by the deposition of the carbonate of lime held in solution. It will been seen that few breccias or conglomerates are more firm, and yet we are certain that the period required for its production could not have exceeded 17 years. A demonstrative proof, many may exclaim, that the immense periods demanded by geologists for the formation of the fossiliferous rocks, are unnecessary. Truly so, I reply, if all those rocks had been concreted by carbonate of lime, which is the fact only of a small part: if their composition and cement had not repeatedly changed: if they all contained the same organic remains, and if no other evidence of slow changes appeared in them. But these circumstances make the inference entirely nugatory.

## *Alluvium of Disintegration.*

Very few rocks have the power of completely resisting the united influence of air, water, heat, and cold. And some kinds are powerfully and deep-

ly acted upon by these agents. Perhaps the new red sandstone is more affected in this manner than any other rock in Massachusetts: and not unfrequently its surface for several feet in depth, is converted into mere sand and gravel. This becomes gradually mixed with the soil, and gives a decidedly red hue to extensive tracts. Next to this sandstone—and I am not sure but even more subject to decay—is our gneiss; especially that in Worcester county. Hence in that part of the State—hilly as it is—we sometimes scarcely see a rock in place in crossing a whole township. In an excavation which I lately noticed in Spencer, I had an opportunity of observing that a disintegration had taken place in the gneiss, from 6 to 10 feet in depth. I could distinguish the materials resulting from disintegration, from the diluvium lying above them, by observing that in the former the masses of gneiss, remaining undecayed, had a position parallel to that of the layers of the solid gneiss beneath, being considerably inclined; whereas the fragments in the diluvium exhibited no such parallelism. I have never seen a disintegration so deep as this in the new red sandstone, though in the vicinity of New Haven, Ct. its depth is several feet. Some varieties of trap rock, particularly one on Connecticut river, whose base is wacke-like, and some of the sienites in the eastern part of the State that abound in iron, disintegrate, and even decompose, rapidly. Mica slate and talcose state are similarly affected, though to a less extent, as is also argillaceous slate, and some varieties of slaty graywacke.

Quartz rock, for the most part, is one of the most indestructible of all our rocks. Those rounded and smooth bowlders of granular quartz especially, that are so common in the western part of the State among the diluvium, appear in general to have bid defiance to all decomposing agencies in past ages, and to be destined to endure unchanged for ages to come. Yet I had recently pointed out to me a rather curious, and somewhat instructive example of these bowlders, lying in the former fruit-tree nursery of Mr. Tracy, in Norwich. It was several feet in diameter, and though not so smooth as some bowlders of this kind, yet I should not have suspected that it had suffered the least waste, were it not for an inscription that appears upon it. The name of John Gilpin is marked on its upper surface, in a large fair hand, a few of the letters only being indistinct. These letters are not cut in the stone, nor do they consist of any foreign substance, like ink, or paint, spread over it. But they are rendered visible simply by the lighter color of the surface, where they were originally written; and by passing the finger over them, it is obvious that they project slightly. Hence I infer that these letters were orignally written with some kind of paint, which prevented the rock beneath it from decaying: while the decomposing process went on gradually on the other parts of the stone. Now as these letters must have been writ-

ten since the settlement of that part of the country, we cannot suppose that more than 150 years at the longest have since elapsed: and probably the period is much less. We have here, then, a sort of measure for determining the rate at which hard quartz rock will decay by atmospherical agencies.

## *Alluvium of Degradation.*

Three causes are constantly operating to degrade the mountains and hills, and to fill up the valleys, viz: rains, frost, and gravity. That they have not already reduced the earth's surface to a level, is decisive proof that the globe has not existed in its present state eternally. It is true that there is evidence along some coasts that the land has risen considerably in quite modern times. And some have maintained that the elevation of land in general by volcanic agency, exactly balances its degradation by aqueous and atmospheric agents. But the leveling process of which I speak, applies to the lofty primitive ranges of mountains upon existing continents, which no slow vertical movement, even of a whole continent, could produce. They must, have been chiefly formed by an upheaving agency more powerful than is now exerted on the globe, while yet our continents were beneath the ocean. And the fact that the unceasing process of waste and degradation to which they are exposed, has not yet reduced them to a level, shows at least, that this process must have commenced in time; and therefore the present state of the globe has not existed eternally.

In precipitous ridges, particularly of trap formation, frost commences the work of degradation. Water, penetrating the fissures of these rocks, expands by freezing and forces them slightly asunder. This makes room for a larger portion of water the succeeding winter; and thus the process goes on until the columnar masses of rock are urged downward by the force of gravity and powerful rains. This is the origin of those extensive slopes of broken fragments, or *debris* of rocks, which arrest the attention on the mural faces of the greenstone ridges in the Connecticut valley. Generally these fragments rise only about one half or two thirds the height of the ridge; though sometimes they continue to the very summit: the process of degradation from this cause having come to an end.

Instances of this kind as above stated, have been regarded by geologists as a kind of natural chronometer, demonstrating the recent orgin of the present state of the globe. No observations, however, have been made on the progress of this leveling process accurate enough to compare it with historical records.

When the three causes of degradation above mentioned combine their maximum energy on the sides of steep Alpine summits, they produce the well known and sometimes terrific phenomenon of *land-slips*. Though examples of these on a limited scale are very common in Massachusetts, yet the only one worthy the particular attention of geologists, is on the southwest side of Saddle Mountain, at the place called the Hopper. But this has been particularly noticed in the second part of my Report.

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### *Hydrate of Iron or Bog Ore.*

In the western part of Worcester county, and over a large extent of territory, the process by which this ore is produced and deposited, is so manifest, that it deserves description. The gneiss rock there, abounds with the sulphuret of iron. This is continually undergoing a decomposition by the action of heat, air, and moisture; and become changed, first into an oxide, and then, some of it into a sulphate. The oxide usually imbibes more or less of carbonic acid from the atmosphere, and is changed into a carbonate; which is soluble in water. Or this oxide, being washed from the rocks by rain into cavities, meets with water containing carbonic acid, by which it is dissolved. Once dissolved, it is readily transported to ponds and swamps, and there deposited by the evaporation of the water. In the region above referred to, this process may be witnessed in all its stages. By breaking the rock we find the sulphuret unchanged; while the surface is coated over with the oxide, sulphate, and carbonate. The soil, also, to a considerable depth, exhibits very strikingly the color of iron rust; and in the low grounds the bog ore is abundant.

Probably a similar theory will apply to the production of this ore in other parts of the State; though I know of no spot where the process is so obvious as in Worcester county. Indeed, the fact that very many of our bog ore deposits are buried several feet deep by soil, and occur on dry ground, shows that in those places the process of its formation has long since ceased. In several ponds in the southeast part of the State, it is said however, that it is forming rapidly.

Since iron is a mineralizer of organic substances, we might expect to find organic remains in bog ore. In that of Massachusetts, I have noticed only vegetable relics. In New Braintree the culms, spikes, and spikelets of grasses—mostly of carex—are common. The spikes and spikelets especially, are very distinct and perfect. (No. 19.) Even the natural color of the fruit is sometimes preserved; and to appearance it seems to be unaltered, but examination shows the whole to be only iron ore. I have a specimen of the trunk of the alder from N. Hampshire, perfectly mineralized by oxide of iron.

### *Hydrated Oxide of Manganese or Wad.*

I know not why geologists have omited this substance in enumerating alluvial deposits. For it seems to have as good claims to be regarded alluvial, as bog ore and peat. I refer particularly to the hydrated oxide, or black wad; which is ordinarily a mixture of manganese, iron, and clay. This is certainly produced daily by a process analogous to that which forms bog ore; that is, the decomposition of rocks containing manganese, exposes that metal to be washed by water into cavities on the surface of the earth, where it either incrusts other substances, or forms a separate

deposit. Instances of this incrustation may be seen every where in the primary region west of Connecticut river; and examples of such deposition I have observed in Leverett, Whately, and Conway. These deposits are sometimes a foot in thickness, and occur in low places, covered only by a few inches of soil. (Nos. 20. 21. 22. 1686.)

## *Power of Ice in the removal of Bowlders in Ponds.*

I am not aware that this phenomenon has been noticed on the eastern continent; and it has been but rarely observed on our own. Its effects in modifying the face of the globe must be very limited; yet they deserve enumeration.

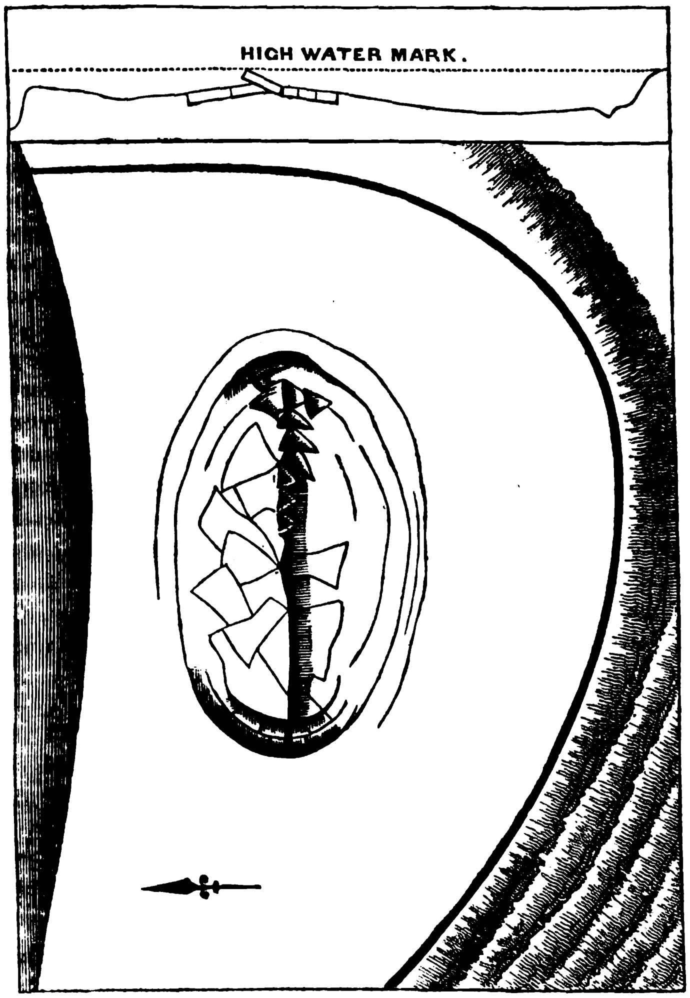
It is well known that water, by an apparent exception to a general law, expands with great force when freezing, and even far below the freezing point. Over a large extent of surface this effect may be very considerable; and when bowlder stones, lying in shallow ponds, become partially enveloped in the ice, they must feel the effect of this expansion, and be driven towards the shore: since the force must always act in that direction. As no counter force exists to bring back the rock to its original position, the ultimate effect must be to crowd it entirely out of the pond; and perhaps to this cause we may impute the fact, that on the margin of some ponds we find a ridge of bowlders; while the bottom, for a considerable extent, is free from them.

The removal of rock masses in this manner was first noticed in Salisbury, Ct.; and a statement published in Vol. 9th, of the American Journal of Science. I have seen no similar instance in Massachusetts; but Rev. Sylvester Holmes, of New Bedford, informs me, that an undoubted example of these traveling bowlders exists in a pond in Carver, Plymouth county; and that their track in the mud is quite obvious.

## *Singular Rent in the Soil by Frost.*

In the year 1818, I examined a remarkable example of rents in the surface of an alluvial meadow in Deerfield, which may properly be noticed in this place, being probably dependent upon the same principle as the removal of bowlders in ponds. The spot was upon the south bank of Deerfield river, near Pine Hill; and has since been entirely worn away by the water. It was then a grass field, elevated 14 feet above the river, whose central part was about 5 feet higher than its east, south, and west border, which consisted of a *swale*, or low marshy ground, through most of which a ditch was dug, communicating at each extremity with the river. Fig. 47. will convey an idea of the situation and nature of this convulsion.

Fig. 47.




On the most elevated part of this spot in the spring of 1818, I found a fissure one inch wide, and 14 inches deep, which formed an almost perfect ellipse, whose longer diameter was 9 rods, and the shorter one, 5 1-2 rods. Within this fissure were several others, nearly concentric to it, but none of them extending around the whole ellipse: and near the longer axis were other rents running in various directions. Along that axis, the greatest effect of the disturbance appeared. The soil, on its south side, to the depth it had frozen during the winter, viz: 14 inches, was raised up and crowded northerly, so as to overlap the north edge about 3 feet: or else the two edges were both raised up so as to stand slanting like masses of broken ice against each other. Yet in most of the other fractures, there was a space between the broken masses; as if they had been withdrawn from one another. At the extremities of the transverse axis also, there was an overlapping of the edges of the earth of about 2 feet, extending nearly 2 rods each way from the axis. The ground beneath the frozen crust did not appear to have been disturbed at all.

In another part of the same meadows I found a second though less perfect example of the same

description in the soil, whose situation and general character were very similar to those above described. Its diameters were 7 and 8 paces.

I impute this unique phenomenon to the expansive power of frost. The month of February had been unusually cold. Its mean temperature was as follows at Deerfield.

At 7h. A. M. 6° Fahr. At 1 1-2 P. M. 24°. At 10h. P. M. 11°. On the 27th. of February, the thermometer stood at 15° below zero; when the cold suddenly relaxed, and a rain succeeded, by which Deerfield river was raised so as to flow over the spot where the rents took place, to the depth of five feet. On the third of March, some boys were sailing near the spot, and noticed a good deal of agitation and bubbling of the water, with an occasional jet 3 or 4 feet high. During the succeeding night a violent detonation was heard by a family living a mile distant, which they said resembled the cracking of the ground by frost, though so powerful as to throw down some of their furniture. The disruption was not discovered till a day or two after; but very probably it was made at that time.

Now the probability is, that the frozen surface of the earth around this spot, had been unusually expanded by the great cold of the winter, and that in the highest part of the field it had been gradually swelling up, without breaking, and the air, forcing its way into the cavity beneath. The water that flowed over the spot would partially thaw and weaken the envelope, and through any fissures that might exist, the air would rush out and throw up the water in a jet, till at length the weight of the water might break the frozen crust and relieve the tension, producing an explosion. The frozen masses of earth along the longer axis and at its extremities would overlap as is shown in the Section at the top of Fig. 47; which crosses the spot from north to south. But as the frozen surface around thawed and contracted, it might cause the outer fissures to separate a little as they seem to have done.

Why may not this alternate expansion and contraction of the frozen surface of the earth, produce in some places, geological changes of considerable importance? Where the soil is very much saturated with water, the effect would of course be most striking. Indeed, it is probable that a soil may contain water enough to make it freeze, and yet so little, as actually to contract by the process.

In the first volume of the American Journal of Science I gave a more particular account of the above occurrence than can be presented here.

## *Action of the Sea upon the Coast.*

It would not be proper in this place to go into the minute details of this subject. Where the combined and often conflicting agency of breakers, tides, currents, and rivers at their mouths, is to be taken into the account, it is obvious that very complicated effects must result: yet in general it may be stated, that the sea sometimes encroaches upon the land, and sometimes makes additions to it. Whether upon the whole these effects are balanced, is a question upon which geologists are divided in opinion. My object is merely to state such facts as have fallen under my notice in respect to the coast of Massachusetts.

### *Encroachments of the Sea.*

The most remarkable example of this occurs in Boston Harbor. Here, as is well known, are numerous picturesque islands, the inner ones, nearly as far as the Boston Light, being composed

chiefly of diluvium; though on their shores, at a low level, not unfrequently we find argillaceous slate and othér rocks that occur on the main land. But all the islands outwards from the Great Brewster, are merely naked masses of rock, and it would be natural to infer that the diluvium had been removed from these, even if we did not actually detect the process. But on the Great Brewster, the work is going on before our eyes. Its eastern side is a high bank of diluvium, obviously wasting away by the action of the waves that roll in upon it from the wide Atlantic; while the extensive beach along its southern side, is composed of the materials that have been swept away from its outer coast. The same process is seen going on upon the outer side of several other islands; and on Deer Island an extensive wall of stone has been erected by the U. States Government to arrest the progress of this degradation; which, if continued much longer there, would lay open the inner part of Boston Harbor to the fury of the northeasterly storms.

It seems to me that no man accustomed to reason correctly from geological facts to their causes, can hesitate, in view of the appearances which these islands exhibit, to infer that all those islands outside of the Great Brewster have been deprived of their diluvial coat by the action of the ocean. Nor when we consider the frequency and violence of northeast winds and storms upon this coast, need we fear that the cause is inadequate to the effect; although it is not less than two and a half miles from the Great Brewster to the outermost of the Graves. It does not, indeed, follow, that all the intervening space between these outer islands was once solid land; so that the ocean has actually worn away 2 1-2 miles; and yet, this seems highly probable. Indeed, the mind is irresistably led to inquire whether the whole harbor has not been produced by the same cause; and when we see so many islands scattered over its bosom, which seem obviously the wrecks of one continuous diluvial formation, and perceive that the rocks, wherever they occur, are only a continuation of those occurring on the mainland, the most cautious reasoner can hardly avoid the conclusion that such was the origin of this harbor: or, at least, that this was a powerful auxiliary cause in its formation. Nay, it is difficult to see why the same reasoning will not apply to the whole of Massachusetts Bay; and when we see with what tremendous force the ocean must, for ages, have battered the hard sienitic rocks of Cape Ann, and what an immense accumulation of sand, gravel, and bowlders, has been made along the south shore of this Bay, we feel almost prepared to adopt this theory. And yet, we are staggered in our belief when we reflect on the immense period of time requisite for such a work; and doubt whether other geological facts do not indicate a later commencement to the present order of things on the globe.

The proper place for learning the dynamical effect of northeast storms upon our coast, is on the northeast side of Cape Ann. Rocks of many tons weight have been in this manner moved from their beds, and driven inward a considerable distance. One has only to visit this coast to be astonished at the marks everywhere exhibited of the powerful agency of a stormy ocean, and to be satisfied that nothing but the extreme hardness and unstratified structure of the rocks has enabled them to resist its violence. And when we learn that the rocks of Boston Harbor are softer and schistose, we see a sufficient reason why they have given away before the breakers; while Cape Ann, and the shores of Cohasset and Scituate maintain their position.

I have received the following statement from Dr. Benjamin Haskell of Sandy Bay, on the northeast side of Cape Ann, illustrative of the power of the stormy waves of the ocean upon that coast.

"The northeast extremity of this Cape, known by the name of Flat Point, differs from the general features of the coast, by extending into the sea with a gradual slope, instead of the bolder aspect of the adjacent shore. Upon this point the sea beats during a northeast storm with a violence conceivable only to those who have witnessed it. Here, at a distance of from 60 to 100 feet above high water mark, lies what a farmer would call a winrow of bowlders, which there is every reason to believe have been thrown up within a few years."

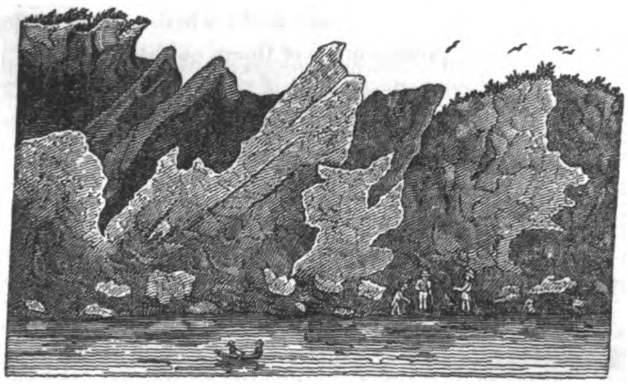
"These bowlders are irregular in form, and angular, their corners being scarcely rounded by

attrition. They exceed in size any thing of the kind in this vicinity. A number of them would weigh 10 or 15, and some even 20 tons. But there is one far more interesting than all the rest; both on account of its greater bulk, and comparative regularity of shape, which renders the former easy to be estimated, and thus affords the means of ascertaining the maximum force of the Ocean in its anger. This rock was originally attached to a ledge about 5 feet above the level of the sea. The broken surfaces correspond so exactly as leave no room to doubt from whence it was detached. From this spot to the spot where it now lies, the direction is south, a little westerly. The distance 106 feet: but between the two positions, there is a hollowing of the ledge, (not a recent one) over which it must have passed, so that the ascent of the rock up this old-fashioned railway cannot have been less than 10 feet."

"The weight of this bowlder has been calculated with care, due allowance having been made for irregularities of surface, and found to be rising of 28 tons. What an illustration of Hydrodynamics?"

Several cliffs of clay and sand along the coast exhibit the combined effects of the ocean, rains, frost, &c., in wearing away the land. In Chilmark, on Martha's Vineyard, is one of these facing the southeast, and at least a mile in length. It is now rare that the breakers rise high enough to impinge directly against the cliff: but they wash away whatever materials have been brought down by the rains. Gay Head, which is the western extremity of the same island, presents a cliff of variegated clays, sands, &c., not less than 150 feet high; and which standing exposed to the buffetings of winds and waves from the sea, and to the wastes of storms from above, exhibits perhaps the most instructive example along the shore, of the effects of these agents. In the second part of my Report, I described this cliff as a most picturesque object of scenery, but there is not likewise a more interesting spot in the State, to the Geologist. And among other things he cannot but notice the numerous fantastic forms into which the lofty masses of clay have been worn, while the numerous bowlders and pebbles along the beach attest the violent action of the sea. The following sketch, hastily taken, will give some idea of the aspect of the northwestern part of this cliff, as seen by a person standing on the beach below, close to the water. To exhibit it in perfection, the various lively colors of the different kinds of clay should be put upon it.

Fig. 48.



*Oblique View of the Clay Cliffs at Gay Head.*

A similar bank of Clay occurs at the Light House in Truro, near the extremity of Cape Cod. It lies exposed to the unbroken fury of the wide Atlantic, and the marks of slow encroachment upon the land are quite manifest. Indeed, it is the prevailing opinion in that region, that this Cape is wearing away along the whole extent of its eastern extremity, and extending farther into Massachusetts Bay on the opposite side. I have no doubt that this is the case. For the general current on that coast is towards the south.

The same I presume is true of a considerable portion of the eastern shore of Nantucket. From data, on which Lt. Psescott places considerable confidence, he infers, that in one place, the loss of land within half a century, has amounted to 3 or 4 rods in width.

This advance of the ocean, however, must not all be imputed to the action of currents. For when once a sand bank of considerable height has been raised on the coast, the sea breezes will drive it inwards farther than the land breezes will bring it back. This inland march is quite obvious on Chatham Beach, in the situation of a swamp, which, 50 years ago, was in the center of the beach; but now lies near the eastern shore; the body of the sands having moved further west. A salt meadow formerly situated on the western side of the beach, adjoining the old north passage into Chatham harbor, has been covered up, and now begins to be disinterred on the eastern shore. A similar change of sides has taken place in a peat swamp on Nauset Beach; which lies north of Chatham Beach, joining the mainland at Eastham.

I have described, in the second part of this Report, two excavations in solid rock in Newport, Rhode Island; one of which is called Purgatory; and these may be taken as a good example of the action of the sea upon a rocky shore.

### *Gain of the Land upon the Sea.*

Very frequently the materials that have been swept away by the sea, are again deposited by tides and currents along the same coast, forming low beaches. This is the case in nearly all the instances on our coast where the land is wasting away. Perhaps the most remarkable example is Chatham Beach, at the southeastern extremity of Cape Cod, which was all probably formed in this manner. On the Cape I was informed that this beach had advanced southerly, during the last 40 years, at the rate of a mile in eight years. Des Barres constructed a chart of this coast in 1772, and he says that the gain of this beach, for 30 years previous to that period, was 2 1-2 miles, that is a mile every twelve years.

An intelligent writer in the Barnstable Journal, however, has recently stated that it has advanced southerly only three miles in 70 years. He says that 20 years ago, this beach was an island; and that there was a good harbor near its northern termination, which is now entirely filled up; so that no identation of the coast marks its former situation. Webb's island, also, situated not far from this harbor, is entirely washed away. In consequence of these changes, it is well known that the harbor of Chatham, once excellent, is nearly ruined; and nothing can save it from complete destruction but the forming of a new entrance.

Nauset Beach, already referred to, has likewise extended, according to the same writer, a mile southerly in 50 years: and it can extend no farther in that direction. In Nauset harbor the salt marsh has so much increased within 40 years, that 300 tons of salt grass are now cut where at that time only flats existed.

Monomoy Beach extends southerly from Chatham towards Nantucket; and has been formed in a similar manner by increments at its southern extremity. Not long ago the sea broke across the northern part of this beach, so that it is now an island.

Sandy neck extends eastward from Sandwich, nearly across Barnstable harbor, and it continues to advance in an easterly direction. There can be little doubt, also, that the whole of Provincetown was formed in the same manner, and ought to be regarded as alluvial.

In like manner Smith's Point, which is a low and sandy beach constituting the southwestern ex-

tremity of Nantucket, has been produced by materials drifted thither by tides and currents from the eastern side of the island. When Des Barres constructed his chart, its extent was nearly the same as at present. But since that time, as Lt. Prescott informs me, it has been from one to two miles shorter. Whether the current that forms this beach passes around the northern point of the island, or along its southern shore, has not been ascertained: but it is certain that a current does set around the northern point, and thence along the northwestern shore, as certain facts prove, which I have not space to mention. And probably it is this current chiefly which has formed Smith's Point; and not unlikely, also, the islands of Thuckanuck and Muskegut, as well as the extensive shoals between Nantucket and Martha's Vineyard. It may be likewise, that another current passes along the south shore of Nantucket, aiding in this work, and forming Nantucket Shoals. And perhaps the irregular action of these currents, aided by unequal tides, may sometimes lengthen out, and at other times curtail the low beach of Nantucket called Smith's Point.

In several other places on the shores of Nantucket, there appears to have been an accession to the land, in the manner that has been described. But I am too ignorant of details concerning these spots, to be able to make any statements of interest about their progress or extent.

Considerations like the foregoing, often lead a man to feel as if such low sandy islands at Nantucket, and others in its neighborhood, were sliding from under his feet. But that no general change of position has taken place in them is obvious from the fact, that some of the cliffs on the shores of Nantucket at least, exhibit regular layers of sand and clay, demonstrating its general structure to be that of a formation, by diluvial or tertiary agency, which has never been removed since its original deposition. True, if the world exist long enough, and the present agencies continue to operate, the whole island will change its position. But as the work has progressed so slowly during the past 6000 years, the time requisite for its completion must be immensely great.

### *Dunes or Downs.*

Sand is frequently thrown by the spray, or waves, during a storm, so high upon the shore, that the reflux waves do not carry it back. This being dried by the sun, is driven inwards by the sea breezes, and in the course of time forms hills of considerable elevation. Or sometimes the wind from the sea raises the sand from a cliff of tertiary formation, and carries it inland. Thus are formed those moving sand hills, which on the eastern continent, are called dunes or downs, and which have excited so much interest near the banks of the Nile. As might be expected, these dunes are common along the shore in the southeastern part of Massachusetts. They may be seen in the greatest perfection and on the largest scale, on Cape Cod; particularly near its extremity. They are frequently as high as 60 or 70 feet, and on the east end of the Cape, they move towards the west, but at what rate, in any instance, I was unable to ascertain. A series of these dunes, several miles long, threatens the village and bay of Provincetown, and large quantities of the beach grass have been transplanted to their ridges for the purpose of arresting their progress. I observed also, that the two species of the

Hudsonia, which are common on the Cape, present no small obstacle to the advancement of these sands; though never transplanted, that I am aware of, for this purpose.

On both shores of Cape Cod throughout its whole extent, may be seen dunes more or less extensive; and by their snowy whiteness they sometimes give great interest to the landscape. I cannot learn that any of them have been productive of such extensive mischief to farms and villages as has sometimes resulted from their progress on the eastern continent. It would be strange, however, if the future history of Cape Cod should not contain catastrophes of this kind. Indeed, I have stated that they have aided in filling up the harbor of Chatham already. And in the west part of the village of Provincetown, I noticed houses about which the sand had accumulated so as to leave the first story nearly below the surface; although the sand was prevented from coming in contact with the house by a wall.

Dunes of small extent, and of low elevation, occur on Nantucket, Martha's Vineyard, some of the Elizabeth Islands, and in many places along the coast in the County of Plymouth. Moveable sand hills also rarely occur in the interior of the State; as, for instance, in the Connecticut valley, in Montague, Hadley, and in Enfield, Ct. But concerning these I know of no facts of special interest, except that they are slowly advancing towards the southeast; indicating the predominance of northwest winds.

One of these, for instance, exists in the east part of Hadley, a few rods south of the road leading to Amherst: and its southeasterly movement is quite evident. For on that side the pines and other trees, which are some 30 or 40 feet high, may be seen deeply buried in the sand.

### *Supposed Agency of Molluscous Animals in producing Geological Changes on the Sea Coast.*

I am indebted for the following suggestions to Dr. James E. DeKay, Zoologist to the State of New York. Though the observations were made upon Long Island, they will most probably apply to the coast of Massachusetts; and it would not be strange if this apparently minute agency should be found, like many other causes apparently minute, to exert an influence of great importance.

"I have resided latterly," says he, "on the shore of a large bay, on the northern coast of Long Island; and the changes effected on its sandy beach by winds, tides, and apparently irregular currents, have attracted much of my attention. It has, however, often been a matter of great difficulty to account for the deposition of materials in places, where, from the operation of the above named causes, they certainly ought not to be found. Will the following facts throw any light on this subject.

"In a calm, still day, I have frequently noticed the surface of the water covered with patches of sand, varying in extent from one to six or eight inches square. These patches are composed, of course, only of the finer portions of sand, adhering to each other by a thin film of gelatinous matter, which gives buoyancy to the mass. I have been surrounded frequently, by patches of this kind, in tolerably close contact, and covering a surface of several hundred acres. The lightest touch of an oar, or a slight breeze, causes them to sink immediately. The rationale of their formation I conceive to be this. The shore we know to be peopled with myriads of minute mollusca, furnishing, either by their excretions, or their own proper bodies, a gelatinous substance, which hardens upon exposure to the sun, aud forms a crust including the subjacent sand. In this state the tide comes in quietly, detaches successive portions of this crust, in larger or smaller pieces, which are borne away by the retreating tide May not this silent and hitherto unnoticed transportation counteract, to a certain extent, the operation of other known agents?

It is not philosophical, I admit, to impute important effects to slight and apparently inadequate causes, but it is equally unphilosophical to neglect trifling phenomena until the nature and extent of their agency has been thoroughly investigated."

I will only add, that I possess some of these sandy films, found on the coast in the southeast part of Massachusetts, to which the dried animals are still attached. I hope the attention of geologists, who are favorably situated for observing this phenomenon, will be excited to the subject.

## *Valleys.*

The man who takes only a hasty glance at the subject, is very apt to impute all valleys to the action of existing streams. But it needs only a slight examination to satisfy the observer that such a cause is totally inadequate to the effect. It will not, for example, explain the very common occurrence of one valley crossing another. Hence geologists have been obliged to resort to several causes to explain all the phenomena. The origin of one class of valleys, they refer to the original elevation and fracture of the rocks by a force acting from within the earth, and hence sometimes called valleys of dislocation. A second class they regard as the result of aqueous action in early times, and hence they are called valleys of denudation. A third class they suppose to result from the agency of existing streams.

Few of the valleys of this country have as yet been geologically described. The subject is a difficult one, and the observer needs to examine long and patiently before he can in many instances satisfy himself in what manner valleys have been produced.

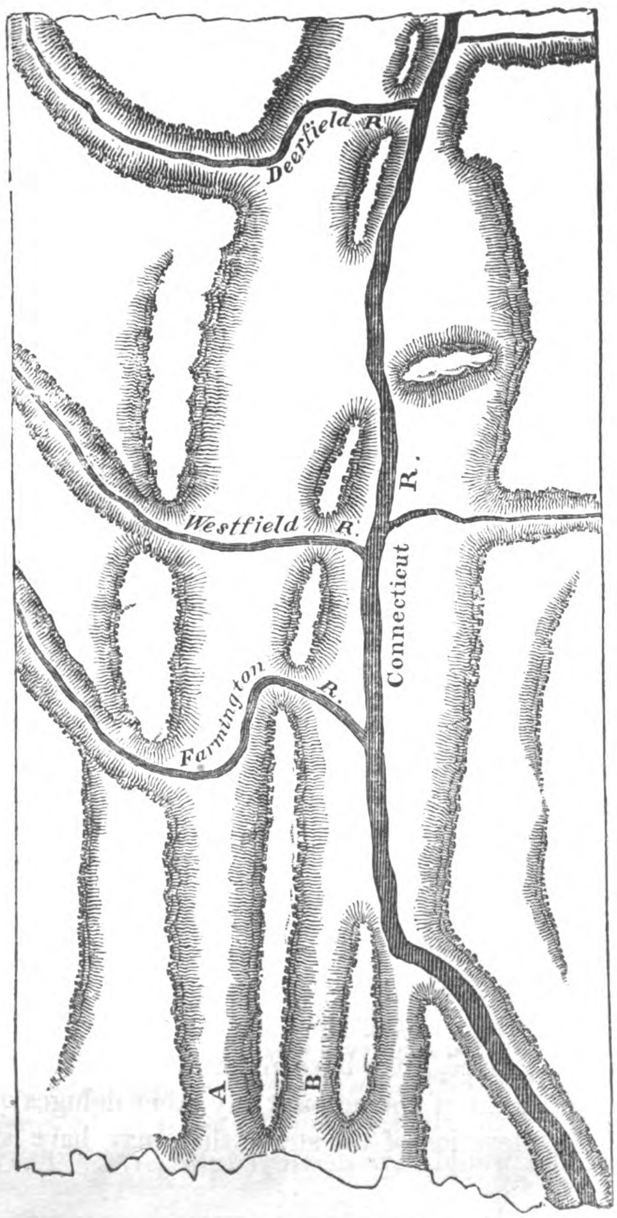
Since many of the vallies of this state must be referred to the original elevation of the strata, it is premature to treat of them all under Alluvium. But as it will be more convenient to consider all the varieties of our valleys together, I shall examine the whole subject in this place.

### *Valleys of Connecticut River and its Tributaries.*

It is now generally admitted by geologists, that all stratified rocks must have been originally deposited in nearly horizontal layers, and subsequently elevated to their present inclined position by a force acting beneath. Such a disturbance must have produced many violent and extensive fractures in the strata and valleys of every shape. And since in the mountainous parts of Massachusetts the strata are mostly primary and highly inclined, probably this is the manner in which most of our mountain valleys have been produced. If the strata were elevated suddenly from the bottom of the ocean, the retiring waters must have acted powerfully upon the irregular surface, and considerably modified the forms of the valleys. The agency of rains, snows, and rivers, since that period, must have given them still farther modifications. Nor ought we to leave out of the account any other deluges of a date subsequent to that of the elevation of the strata, that may have swept over the land.

The valleys through which the Connecticut and its tributaries flow, are the most remarkable in the State. The ordinary laws of physical geography seem here to be set at defiance; so much so, that a late ingenious writer* doubted whether I had correctly represented the 'Geology of the Connecticut,' because the course of the rivers, and the direction of the mountain ridges, were described as having so little correspondence with the rock formations. But the features of the geology, as well as of the scenery, along this river, are too obvious to be easily mistaken in their great outlines, which are alone concerned in this inquiry. The relation of the rivers to the different mountain ridges and rock formations, I hope to render intelligible by the aid of Fig. 49, on which are traced only the chief outlines of the surface. To present all the smaller irregularities of surface, I found would only obscure the points which I wish to illustrate.

Fig. 49.




*Valley of the Connecticut.*

* Darby's View of the United States, p. 164.

That portion of the valley of the Connecticut to which I shall specially refer at this time, extends from near the north line of Massachusetts to Long Island Sound at New Haven. It is bounded by broad and generally lofty primary mountains: which, at the northern and southern extremities of the valley, converge until they almost meet. They are farthest asunder about in the latitude of Hartford. This valley is divided diagonally by a ridge of greenstone; commencing on the south with West Rock at New Haven, and extending, with few interuptions, to Easthampton, where it attains an elevation of about 1,000 feet, and forms Mount Tom. Here it crosses the Connecticut, and on the opposite bank, forms Mount Holyoke; and continuing a few miles farther, terminates in Belchertown, as already described in the second part of this Report. This greenstone range is separated by valleys from the primary ranges at its extremities; and there are several places where it almost entirely disappears, as at the point in Hamden, through which passes the Farmington Canal: unless any are disposed to regard Mount Carmel in that town, as the southern extremity of the range, and the hills to the southwest, as a distinct range. Several other hills and elevated ridges of less extent, occur in this valley; but it is unnecessary in this place to describe them.

In tracing the Connecticut through this valley, the geologist will be surprised to find it crossing the grenstone ridge above described, and that too in its highest part, viz. through the gorge between Holyoke and Tom. For he will naturally inquire, why did not the river flow through the valley A, west of the ridge: and following the course of the Farmington Canal, empty at New Haven? For it appears from the surveys on that Canal, that in no place is that portion of the valley more than 134 feet above the present level of the Connecticut at Northampton: whereas the ridge through which it passes is from 800 to 1000 feet high. But the surprise of the geologist will be still farther increased, when he finds this river at Middletown, quitting the great valley above described, and passing over the remainder of its course through a deep ravine among primary mountains, instead of passing to the Sound through the valley B, now traversed by the Hartford and New Haven Rail Road, and which is scarcely higher than the streets in Hartford, in any part of its course.

What inference shall we deduce from these remarkable facts? Why, surely, that Connecticut river did not excavate its own bed through these mountains; for had the barriers at Northampton and Middletown been more than 134 feet above its present bed, it must have emptied into the Sound at New Haven. We must seek some other cause, therefore, for the origin of the passage between Holyoke and Tom, and for that through the mountains below Middletown.

Another inference is, that if the Connecticut ever formed a lake in its present valley, it must have been rather limited and shallow. For every place 100 feet higher than Northampton meadows at present, must have been above the waters; and on the east side of the greenstone ridge, they must have been still more shallow. It may perhaps be thought that a barrier might have formerly existed at New Haven, which was subsequently worn down. But this would have been too mighty a work for any transient deluge to accomplish; and the idea that the land was for a long time sunk beneath the ocean after the existence of the river, so as to be acted on by currents, cannot be admitted, because this would have destroyed the river. The existence of an

**extensive deposit of clay and sand along the Connecticut, however, with horizontal strata, renders it probable that this river did once form a lake in its present valley; but it appears to have been simply the retiring diluvial waters.**

Not less remarkable than that of the Connecticut, are the beds of its principal tributaries, the Deerfield, the Westfield, and the Farmington rivers. As may be seen on Fig. 49, these all cross a high ridge of greenstone before they reach the Connecticut: and in the case of Deerfield river particularly, the gorge through which it passes, not less than 250 feet deep, appears as if it must have been worn down for the purpose of suffering the river to pass. And yet, this river has only to rise 80 or 90 feet above its present bed, in order to find a direct passage to Connecticut river on the south side of Sugar Loaf mountain. And so the Westfield and the Farmington might have passed down the western part of the Connecticut valley, and emptied at New Haven, had their beds been 100 or 130 feet higher than at present. And such must have been the course which all these rivers would have taken, had not the gorges through which they now pass in the greenstone ridges, been excavated for them before they began to flow, at least, to a considerable depth.

The direction of the primary strata, and the general course of the valleys in the mountainous region on the west side of the Connecticut valley, is north and south. But instead of following these valleys, Deerfield and Westfield river flow through ravines, running in general across the strata, and across the general course of the valleys. These ravines are, for the most part, very narrow and deep, and the edges of the strata on their opposites sides correspond. Where they have crossed the principal ridges, their depth cannot be less than 1000 feet, and often it is more. And yet the strata correspond so accurately in dip, direction, and nature, on opposite sides of these ravines, that there seems to be no way of explaining their origin but by fluviatile action. That they have lowered their beds at least some hundreds of feet, is perfectly demonstrable. For on Deerfield river, a little west of Shelburne Falls, the river now passes through a cut in the rocks some hundreds of feet deep; and passes around a projecting ridge, over which the road to Buckland and Charlemont passes. On the top of this ridge, close by the road, the marks of the former bed of the river, where it cut a gorge through the rocks, is too obvious to be denied by a careful observer. One is amazed that these marks are not obliterated by disintegration, when he looks down into the gulf through which the river now flows. For its excavation must have required a great length of time. Probably the whole ravine through which the river now passes in Shelburne, Charlemont, and Zoar, might have been excavated by the slow action of its waters, in a period not more than three or four times longer than that which must have been consumed in sinking its bed to its present level from the level of this ancient gorge.

In the north part of Russell a similar ancient bed of the Westfield river is still more manifest, and of greater extent than that just described. In this case however, the present bed has not been lowered so much since the river was diverted into it, as is the case in Deerfield river. Yet it has sunk enough—certainly not less than 100 feet—to impress the mind with the idea of a long time as requisite to its accomplishment.

I am not familiar enough with the bed of Farmington river among the primitive mountains, to be able to state any thing definite concerning its origin. But in respect to those of the Deerfield, and the Westfield, I cannot doubt but they have been chiefly formed by their own waters. Yet when a man sees how almost imperceptible is the action of water upon primary rocks, during his life time, he cannot but be deeply impressed, as he stands upon the edge of one of these ravines, and tries to conceive of the period requisite for its erosion by waters that are moving so gently a thousand feet below him, and almost invisible by distance. A similar feeling comes over him as he wit-

nesses such gorges as those already described in Royalston, in Leyden, and especially in Mount Washington, which he is certain must have been solely the result of water. And yet the commencement of these operations must have been among the most recent of geological changes, to which this hoary earth has been subject. How is the most distant event which chronology discloses almost crowded into the present, when brought into comparison with these periods which chronology cannot measure!

## *Terraced Valleys.*

Even though it may be thought doubtful whether the rivers under consideration have excavated the very deep ravines in the primary rocks through which they now flow, yet there is evidence of another kind, in the phenomena of Terraced Valleys on their banks, that they have considerably lowered their beds, since they first occupied them.

Between the primary mountains, from whence Deerfield and Westfield rivers, for example, issue, and the greenstone ridges through which they pass, they have formed alluvial basins, somewhat extensive, and sunk about 90 feet below the general level of the bottom of the Connecticut basin. And the banks of these basins are in some places curiously terraced; the different terraces being on a level on opposite sides of the basin. If we start from the edge of the stream at low water, and ascend a bank of 10 to 15 feet high, we shall come upon an alluvial meadow, which is frequently overflowed; and is consequently receiving yearly deposits. This may be regarded as the lowest terrace. Crossing this, we ascend the escarpment of a second terrace, 30 or 40 feet in height, which may be seen at intervals on the same level on all sides of the meadow. This second terrace is rarely very wide in any place, and seems to be only the remnants of a meadow, once much more extensive, which has been worn away. Ascending from this second terrace, 40 or 50 feet, up another escarpment, we reach the plain that forms the bottom of the great valley of the Connecticut. This constitutes the upper terrace.

The above description applies to the principal terraces existing on Westfield river, one or two miles west of the village, as well as those one or two miles east; and to those in Deerfield meadows, as well as those on the same river in the upper part of Charlemont. Smaller ones occur farther up the stream on Westfield river; also on one of its tributaries; and on Green river, a tributary of the Deerfield. I have also noticed imperfect terraces on Blackstone river, below Worcester. One quite distinct may be seen in West Brookfield, on a small branch of the Chickopee, which passes through that place. In short, terraces more or less distinct, exist on almost every stream of much size in the State, wherever the banks are low enough to admit of alluvial flats.

The banks of the Connecticut are less distinctly terraced in Massachusetts, than the smaller streams that have been noticed. Yet terraces exist on that river in several places within the limits of the appended geological map. In Vernon, a few miles south of Brattleborough village, two quite distinct terraces may be seen on the west bank of the river. Between Turner's Falls

and the mouth of Miller's river, the same number appear, though less distinct. In passing southerly, we find the same number on the west bank, in Pine Nook meadows, in the southeast part of Deerfield. In the south part of Sunderland, and north part of Hadley, on the east side of the river, two terraces appear, although they are at a greater distance than usual from the river. Traces of them appear also, in Springfield and West Springfield. In most of these cases they are discoverable on only one side of the river.

This peculiar arrangement of the sides of valleys, although scarcely ever noticed by geological writers in this country, appears to be very common on both sides of the Atlantic. Dr. Bigsby notices a striking case in Lower Canada; and Dr. Macculloch represents them as numerous in Scotland.

It has been usual to impute terraced valleys to the sudden bursting of the barriers of a pond or lake, through which the stream flowed; or to the sudden removal of an obstruction in a river, whereby its bed was rapidly deepened in soft soil, higher up the stream than the obstruction. If, for instance, the greenstone barrier through which Deerfield and Westfield river now pass, had been suddenly sunk a number of feet by some convulsion of the earth, or powerful ice flood, their beds would have been rapidly sunk by the waters in the soft meadows above the barriers; and thus terraces might have resulted. But I may be permitted to doubt whether any sudden reduction of the river's bed is necessary to account for this phenomenon.

Let us suppose a period, when the bed of Connecticut river, in the mountainous region below Middletown, was yet so elevated as to cause the waters to overflow the great basin between New Haven and Vermont, shown on Fig. 49. At that time, the mouths of Deerfield and Westfield rivers would have been on the western margin of this lake, or in the places where they now issue from the primary mountains. As the Connecticut wore down its bed, the lake would gradually drain off, leaving the formation of clay and sand which the waters had deposited, perhaps 100 feet thick upon an average, with an almost entirely level surface. The Connecticut, having found its present bed, and the waters being drained from the valley, Westfield and Deerfield rivers must also excavate beds in the formation above described, in their course to the Connecticut. Their course would no doubt at first be extremely serpentine as that of rivers usually is, in flat countries. But as the bed of the Connecticut gradually sunk lower and lower, so would the bed of its tributaries sink: and then, would their waters, often swollen by rains, and obstructed by ice, begin to wear away the projecting banks, and convey them into the Connecticut. At length, the banks on either side of the rivers would be worn down and removed for a considerable extent. In other words, such basins as now exist at Deerfield and Westfield, would be produced; less deep, however, and destitute of terraces. As this basin enlarged, another process would commence. While the stream was confined within narrow limits, the alluvial matter, brought down from the mountains, would be carried along to the

Connecticut. But as the basin enlarged, the water, when swollen by rains and melting snows, would spread over it, and becoming more calm, would deposit the mud and sand in suspension. Thus the new formed basin would be gradually filling up, and form an alluvial meadow. But as the bed of the river would continue to sink, ere long the waters would rarely rise high enough to overflow the meadows: and for the same reason they could never be raised by alluvial deposition to the level of the plain through which the river first began to flow. The banks of the river having now become high, the waters would again commence their depredations upon them, and scoop out a second basin from the meadows just described. At length all these meadows would be carried away by the stream, except occasional patches, which would form a terrace around their margin. The second basin, having now become large enough to enable the overflowing waters to begin to deposit their mud and sand, a second meadow would be formed, which would go on rising and the river sinking, until the floods could no longer spread over them; when a third basin would be formed; and so on, as long as the river continued to excavate its bed.

I have confined this illustration to the basins of Westfield and Deerfield rivers, in order to render it more intelligible. But it can easily be applied to the Connecticut, or any other river.

When terraced valleys exist on the sea coast, and are open to the sea, some writers have imputed them to the successive elevations of the land by earthquakes. (Lyell's Geology, Vol. 2, p. 282.) But in all the cases which I have described in the interior of Massachusetts, this explanation is entirely inapplicable; as a knowledge of the local situation of these terraces will make obvious to any one. For the spots where these terraces exist, are separated from the ocean by barriers, which must have prevented the access of the sea, even though the present levels be much higher than they were formerly. On the Connecticut river for example, below Middletown, the barrier consists of mountains several hundred feet high, of primitive rocks; and at South Hadley it consists of a ridge of trap through which a gorge is cut not more than 100 rods wide. True, the ocean might have flowed into this valley by the way of the Farmington Canal, or the Hartford and New Haven Rail Road: But most of these terraces are below the level of those valleys, and, therefore, could not have been formed by tides setting through them. And the theory under consideration requires that these terraces should constitute the shore of an estuary, between the epochs of successive vertical movements. This they could not have done in the present case.

But the most perfect specimens of terraces occur on the banks of Westfield and Deerfield rivers, where they form the banks of basins sunk in the diluvial clay and sand of the valley of the Connecticut, nearly 100 feet. These basins are cut off from opening into Connecticut river by high trap ridges, which have been already described, through which the streams pass in a very narrow gorge, and consequently no water current setting back from that direction could have formed the basins. And had the valleys along the route of the Farmington Canal and the Hartford and N. Haven Rail Road, been once so low as to allow the ocean to get into them, the inevitable effect would have been to fill up instead of excavating such basins as those upon Westfield and Deerfield rivers: for if we suppose that what I call the diluvial clay and sand were brought into the valley by the ocean, no reason can be assigned why they should not have been spread

over the valleys now occupied by Deerfield and Westfield, as well as any other part of the Connecticut valley. In short, whatever hypothesis any one may adopt of the *modus operandi*, no one can examine these spots without being satisfied that these basins and their terraces must have been formed by the rivers themselves. And if such perfect terraces can be formed by rivers in the interior of a country, by existing rivers, why may they not be produced at the mouths of rivers on the coast? The hypothesis which I have advanced to explain the mode in which their waters may have formed them in the interior, applies equally well to their formation on the coast, especially if we admit the coast to be gradually rising. In Massachusetts, however, none of the small streams that empty into the ocean show any terraces at their mouths: nor have I seen any evidence of the rise of that coast, except in very ancient times: and this may be the reason why we find no terraces on the river's banks.

## *Bed of Connecticut River.*

Judging only by the eye, I think we may safely state that since the Connecticut and its tributaries began to flow through the great valley that has been described, they have excavated their beds nearly 100 feet. The Connecticut at Northampton is still more than 100 feet above tide water at New Haven. At Springfield it is only 64 feet. This will give a descent from the latter place to the ocean of only a foot per mile, and considerably less if we subtract the height of Enfield Falls. South Hadley Falls make the principal difference between Springfield and Northampton. Indeed, the medium descent of this river from the foot of Turner's Falls in Gill, is probably less than a foot per mile. This is too small to enable the water to produce scarcely a perceptible effect in lowering its bed, for centuries, nay, not enough to prevent their filling it up. So that probably the process of excavation in the bed of that river, has nearly ceased.

## *Ice Floods.*

There is, however, one agent of excavation, that still operates to some extent, even in the Connecticut; and that is, *ice floods*. Still more powerful is their effect upon smaller and more rapid rivers. Whoever has not witnessed the breaking up of a river in the spring after a severe winter, when its whole surface has been covered by ice several feet thick, has but a faint idea of the prodigious force exerted at such a time. The ice, high up the stream, is usually first broken in pieces by the swollen waters. Large masses are thus thrown up edgewise, and forced underneath the unbroken sheet, and the whole bed of the stream is blocked up; perhaps too, where the banks are high and rocky. The water accumulates behind the obstruction until the resistance is overcome; and the huge mass of water and ice urges on its way, crushing and jamming together the ice which it meets, and thus gaining new strength at every step. Often for miles the stream, prodigiously swollen, is literally crammed with ice, so that the water disappears; and a slowly moving column of ice is all that is seen. This presses with such force against the bottom and sides of the stream, as to cause the earth to tremble, like heavy thunder, to the distance of miles. Sometimes the body of ice becomes so large, and the friction so great, that the waters are unable to keep it in motion; and it stops while the river is turned out of its channel, and is compelled to flow in a new bed for weeks and even months.

It is impossible that such floods should not operate powerfully to modify the surface in alluvial regions, and to excavate the beds of rivers. I am confident that no other agent in the mountain torrents of this state is so energetic. One has only to examine the banks and beds of a river after the ice has disappeared, as I have often done in Deerfield, to be convinced of this. But I apprehend that the maximum effect is seen in those rocky ravines, through which such rivers as the Deerfield and the Westfield pass, in the primary regions. Masses of rock of various sizes, even 10, 15, or 20 feet in diameter, may here be seen, some of them torn up from their beds and

removed a considerable distance, strewing the bottoms of the streams, and at low water almost covering the surface; and others, only partially lifted from the parent rock, and waiting for another convulsive effort of the torrent to detach them, and give them an erratic character. In short, one sees in such streams a cause fully adequate to the production of those numerous bowlder stones that are scattered over the country: I mean, a cause sufficient to detach and round them. Probably, however, the expansive agency of water, frozen in the seams of these rocks, contributes not a little to lift them out of their original beds.

### *Subterranean Streams.*

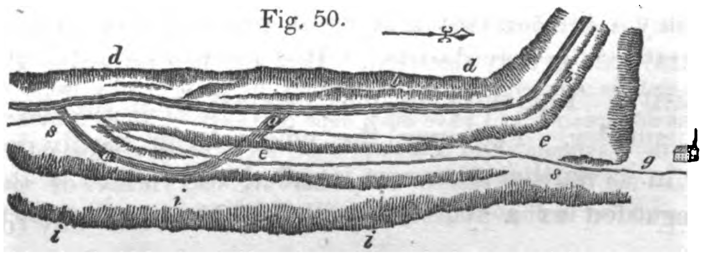
In limestone countries it is very common to find subterranean water courses, either dry, or occupied by existing streams. Those which I have met in Massachusetts are so few, and of so limited extent, that they require but a slight notice. The Natural Bridge on Hudson Brook may be regarded as an example of the latter kind. But this has been already described in treating of the scenery of the State. The cave in the northwest part of Lanesborough is an example of the first kind: but enough has also been said concerning this. At the north base of Saddle Mountain in Williamstown, are two small streams whose usual beds suddenly become dry by the disappearance of the water, which does not appear again for several rods.

### *Change in the bed of Green River.*

A hundred rods south of the village of Greenfield, on the stage road to Deerfield, Green River, a tributary of the Deerfield, has left indelible traces of having once run in a channel 40 or 50 feet above its present bed. At that elevation, a ledge of sandstone rocks bears the marks of having been once the bed of the stream, as distinctly as if it had run there but yesterday. The water here formed a cataract, 20 or 30 feet high; and below the ledge, a chasm, nearly as wide as the present bed of the river, is worn in the rocks several rods long, which communicates with the present channel. The pot holes left in the ledge of rock are some of them 6 or 7 feet deep, and one or two feet in diameter. The hill of sand and clay, which now rises abruptly on the west side of the present stream, probably once extended as far east as this cataract and chasm; and here was a ridge, which threw back the waters of the stream over the whole of Greenfield meadows, 4 or 5 miles in extent. For in various places along these meadows, we find terraces; generally two, but never more. The hill of sand and clay, at this gorge, was probably worn away gradually; and as the surface of the sandstone rapidly slopes towards the west, this would cause the bed of the river to sink, and the terraces to be formed. In this way the bed of the river has changed laterally 10 or 12 rods, and sunk 40 or 50 feet.

Perhaps the following sketch may assist in rendering the preceding statement intelligible. It may not be entirely correct but it exhibits the principal features of the spot.

Fig. 50.



*a*, *a*, former bed of the river.
*b*, *b*, terraces: these are in the upper part of the gorge, and not in Greenfield meadows.
*d*, *d*, level of the Connecticut valley: a tertiary hill with steep declivity.
*e*, *e*, sandstone ledge.
*g*, Meeting House in Greenfield.
*s*, *s*, stage road to Deerfield.
*i*, *i*, *i*, successive ridges of sandstone more elevated than *d*. *d*.

## *Synclinal Valleys.*

I have already stated in general terms, that most of the valleys of Massachusetts owe their origin to the elevation and dislocation of the strata. This is obvious from the fact that these valleys, with the exceptions that have been described, correspond in direction with the strike of the strata. In two instances at least, I think we can see how the elevation of the strata produced valleys.

By a reference to the sections of the strata in Massachusetts appended to this Report, it will be seen, that with the exception of the sandstone and diluvium, the strata on both sides of Connecticut river dip towards the river; thus making the valley through which it runs a synclinal valley. This, however, is an account of the valley before the deposition of the sandstone. That deposit, as I shall soon attempt to show, probably nearly filled the valley. And subsequent to its deposition, a second elevating process took place, which tilted up the western edge of the sandstone several degrees, as shown upon the Sections above mentioned. Afterwards extensive denudation of the sandstone took place, by which the valley was brought into its present state; in which it may still be regarded in some sense as a synclinal valley, and in some sense, as a valley of denudation: that is, it owes its present condition to both these causes.

By consulting the details which I shall give in this report, of the dip and strike of the strata, it will be seen that there are several exceptions to the facts which go to prove the valley of the Connecticut to be a synclinal valley: that is, in many places the primary strata do not dip towards the valley. But in such a case we must take the predominant dip for our guide. On the same principle, it will be seen that the valley running through the center of Worcester, and through the north part of Middlesex and Essex counties, is a synclinal valley. On the east and south sides of this valley, the dip towards its central axis is very decided. But on the opposite sides there is more irregularity. This may in part proceed from the fact that the dip there is much smaller. Yet upon the whole, I can hardly doubt but this valley, which in its northeastern part is called the valley of the Merrimac, should be regarded as a synclinal valley. Nor has any other deposit

but alluvial and diluvial ones, been made in it since the elevation of the strata.

The occurrence of unstratified rocks—greenstone and granite—in the valley of the Connecticut, renders it probable that a fissure existed in the primary strata, through which unstratified masses were protruded. Very likely, also, a fault was produced; but the depth of the sandstone and unconsolidated rocks above the primitive, prevents us from obtaining any evidence of such a dislocation, except from analogy.

I strongly suspect that overturnings and dislocations on an enormous scale, have been the origin of the deep valleys of Berkshire. Yet none of them are properly speaking synclinal valleys; as may be seen by reference to the Sections of the strata in that part of the State. And I have reason to suppose also, that denudation has extensively modified those valleys since their original formation: as I shall shortly attempt to show. But I shall not in this place bring out my views fully in regard to the mode in which the strata have been elevated and dislocated, because it cannot well be understood in so early a part of my Report.

### *Valleys of Denudation.*

The vast amount of detrital matter spread over the earth's surface, evidently composed chiefly of comminuted rock, leads to the expectation that the rocks in place will bear marks of deep erosion. And the longer the geologist examines valleys, the more convinced will he become, of the enormous scale on which this denundation has taken place: for valleys thus produced are called *Valleys of Denudation.* Strictly speaking, *terraced valleys* belong to this class: but as they are obviously the result of alluvial agencies, it has been customary to describe them under a separate head, as I have done.

The evidence of extensive denudation in the valley of the Connecticut, is more decided than in any other part of the State: And yet, I can hardly doubt that as great an erosion of the surface has taken place over the whole State; though the proof is less convincing. And persons not familiar with geological investigations will probably regard many of the suggestions which I am about to make under this head, even where I consider the proof of denudation the strongest, as startling and extravagant hypothesis, rather than legitimate inferences. But after long examination and reflection, I do not know how to escape from the conclusions, at least, so far as to consider them probable.

What I call the valley of the Connecticut, is a trough shaped depression extending from the north line of Massachusetts to New Haven on Long Island Sound. It would be proper to consider the depression through which the whole river flows, from the upper part of New Hampshire to Long Island Sound, as embraced in this valley; and to reckon its width from the summit of

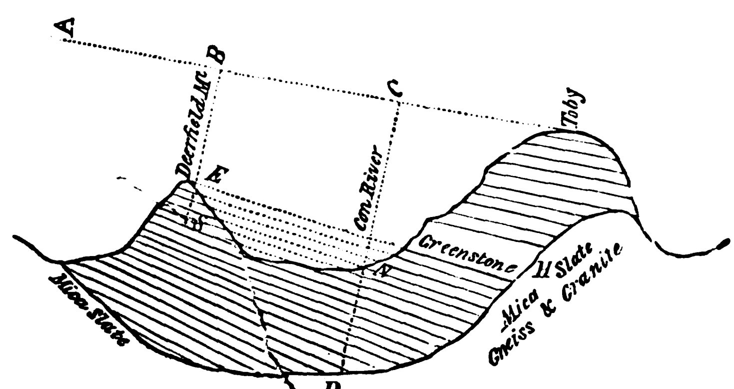
the bounding ridges. But I shall include in the term, only that part of the valley now occupied by secondary sandstone and trap: which is in fact the bottom of the valley with the immediate bounding slopes of primary rocks, extending from Long Island Sound to the north line of Massachusetts. At the latter place, the primary mountains crowd down close to the river, leaving the valley very narrow, although north of that line the valley again opens and closes several times. But no secondary rocks are found in it north of Massachusetts.

By comparing Fig. 49 with the Geological Map, it will be seen that the portion of the Connecticut valley of which I speak, contains several ridges of greenstone and sandstone Of the latter, the most remarkable examples are Mount Toby in Sunderland, and Deerfield Mountain, commencing with Sugar Loaf and extending north nearly across the state. Indeed, the sandstone south of these elevations forms hills nowhere except in connection with trap; which, in most places, overlies the sandstone. Now the sandstone formation, throughout its whole extent, has been tilted up since its deposition, so as to dip nearly to the east from 10° to 20°; and in a few places much more than this. But the average dip does not probably exceed 15°. The strata on Toby and Deerfield Mountain have the usual dip and direction of the whole formation.

Between these mountains flows Connecticut river, in a valley but little wider than its bed, and the question that now arises is, whether the red sandstone formation once extended over the whole valley, between this spot and New Haven, as high as the top of Toby; and whether it has been worn away in the process of ages. That Toby and Sugar Loaf have been worn into their present form by the action of running water, will be admitted by all who will carefully examine them: and I incline to the opinion, that the same agency has swept away sandstone from the other parts of this valley of a depth nearly equal to the height of these mountains. That some inequality might exist in the surface of the formation, at its original deposition, and still more be produced by the causes that have tilted up the strata, I will admit, yet for reasons to be soon stated, I cannot suppose this inequality to be very great.

As to the thickness of the formation under consideration, we have not sufficient data for forming a very definite opinion. Perhaps, however, we may estimate, by examining an east and west section of the formation, across the south part of Deefield mountain, and the center of mount Toby. The following sketch is not intended to be precisely accurate; but only to give a general idea of the relative situation of the two mountains and the intervening valley, with the valleys between them and the primary rocks on the east and west. There must always be as is well known, more or less of distortion and want of proportion in sections of this kind, where the horizontal scale must be much smaller than the perpendicular one. In the present case, in order to exhibit the proper dip of the strata, the valley through which the Connecticut flows, is represented too wide.

Fig. 51.



It will be seen by this section, that the strata, both in Deerfield mountain and mount Toby, as well as in the valleys, have the medium easterly dip of the formation: that is about 15°, though on a considerable part of mount Toby, it is hardly 10°. Two or three hundred feet above the river, on the east side, may be seen a mass of greenstone: which, so far as I can ascertain, constitutes a bed in the sandstone, and divides the upper part of the formation from the lower, the characters of the two groups, being considerably different. Deerfield mountain, in its southern part, consists entirely of the lower beds; and the strata on the opposite side of the river beneath the greenstone, correspond in dip and general characters with those of this mountain. Mount Toby is probably not far from 1000 feet above the river, and Deerfield mountain varies frem 500 to 700. The enquiry now is whether the formation was originally of this height throughout its whole extent, and has been subsequently worn away, except these ridges: or whether these have been raised so much above the general level by a force acting beneath. The latter supposition would seem most probable, were it not for the proof exhibited by the above section, that no peculiar disturbing force has acted on these mountains. Had that been the case, either their strata would exhibit a different dip from the formation generally, or they would not correspond on opposite sides of the river. It seems to me rather probable after inspecting both these mountains, that almost the only change their strata have undergone, was their original elevation about 10° to 15°, along with every part of the formation. And hence we are compelled to suppose, that the top of mount Toby exhibits nearly the original elevation of the whole formation. For the idea that such insulated peaks and ridges, as those under consideration, were deposited in the insulated and inclined position which they now occupy is perfectly absurd. Further we must suppose that the strata of mount Toby originally extended to the top of Deerfield mountain; as is represented by the dotted line *A C* in the section. Nay, on this supposisitton, all the strata of both mountains may have extended to the western side of the valley, as at *A*.

The immense period requisite to wear away such a mass of rock as this theory supposes to have once occupied the whole valley of the Connecticut, will seem to most minds the strongest objection against its adoption: I mean supposing it to have been effected by such causes as are operating at present. But this is not a solitary example, in which geological phenomena indicate the operation of existing causes through periods of duration, inconceivably long. We may in this case indeed, suppose the occurrence of other agencies in the earlier periods of our globe. Still, even with this aid, the work must have been immensely protracted. And why should we hesitate to admit the existence of our globe through periods as long as geological researches require: since the sacred record does not declare the time of its original creation: and since such a view of its antiquity enlarges our ideas of the operations of the Deity, in respect to duration, as much as astronomy does in regard to space? Instead of bringing us into collision with Moses, it seems to me that geology furnishes us with some of the grandest conceptions of the Divine Attributes and plans to be found in the whole circle of human knowledge.

The objection of a writer in the American Journal of Science,* that such a height of waters as would deposit mount Toby, must have produced a lake nearly to the upper part of New Hampshire, in the Connecticut valley, and thus have caused the same sandstone to be produced higher up that valley than Northfield, loses its force, when it is recollected that this formation was deposited before its strata were elevated. For the elevating force undoubtedly changed the relative level of different parts of the country. In this case, the disturbing force must have acted beneath the primary rocks. And besides, we have evidence, which will be shown by and by, that our new red sandstone was formed beneath the ocean. We cannot then reason on this subject from present levels.

If the preceeding statements and reasonings be correct, in order to ascertain the actual thickness of the new red sandstone strata in the Connecticut valley, above the river, we must add the

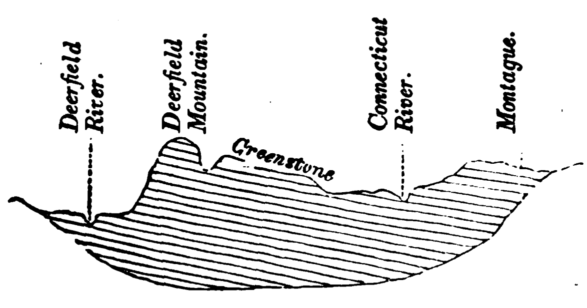
* Vol. 22, p. 223

height of mount Toby above the strata seam $E\ H$, to the height of Deerfield mountain: that is, $B\ E$ to $E\ S = C\ N$. It certainly will not exceed the truth to call $B\ E$ 800 feet, and $E\ S$ 400= 1200, the thickness of the strata above the bed of the Connecticut. In no place that I know of has this river cut through the sandstone: and hence we are almost entirely destitute of means of ascertaining the thickness of the strata beneath the river. If the primary strata have the same slope beneath the sandstone, as above it, this rock cannot be less than 1000 to 2000 feet thick, beneath the river, or $N\ D$. But this is little better than conjecture: both because the slope of the primary strata is very unequal in different places, and because probably the surface beneath the sandstone, is as uneven as it is in other primary valleys: which is evinced by the curved structure of the sandstone strata in some places.

In the second part of my Report I have described the cave and fissure in Sunderland, as having been produced by the wearing away of the inferior schistose strata, probably by water. There is another fact which the observer will notice in various places on the western declivity of Toby. The thick sandstone and conglomerate strata are often arranged in steps or terraces of great height and thickness. At first view the mountain would seem to have been elevated by successive throes of some internal force; each paroxysm throwing up the central part of the mountain higher, and higher, so as to produce these offsetts. But there is too much regularity in the stratification to admit of such a supposition. I should rather impute this terraced structure to the action of those currents of water, which have excavated the valley of the Connecticut. The rock exhibits occasionally a jointed structure nearly at right angles to the strata: hence currents of water, frosts, &c. would remove successive portions as wide as these joints. On some of the terraces huge masses of the rock yet remain, raised from their original bed and irregularly mixed, but not far removed.

It will be seen on the accompanying geological Map, that the greenstone ridge which is marked in Sunderland, crosses the Connecticut in the north part of that town and then forms its western shore as far north as Gill. The section that has just been given crosses the Connecticut a little south of the place where the greenstone crosses the river; and consequently the greenstone is represented as on the east side of the river with the sandstone beneath and above it. But north of the place where the greenstone crosses the river, through the whole extent of Montague and Deerfield, the following section represents the relative situation of the two rocks.

Fig. 52.




Now I cannot but regard this fact as some evidence that the valley between Deerfield mountain and Toby, has been to a great extent excavated by water. For I can hardly conceive how so deep a gorge should have been produced in this greenstone ridge or dyke, at the period of its protrusion: certainly not without causing great disturbance in the adjoining strata; of which I have seen no traces. The continuity of this ridge is uninterrupted; as are the dip and direction of the sandstone strata. But the whole aspect of this valley, and especially, the contour of

Sugar Loaf, correspond with the idea of excavation by water. The rocks in place, too, on both sides of the river, to the height of several hundred feet, bear the marks, in numerous grooves, of powerful abrading agents. When treating of diluvial action I shall endeavor to show, that probably a great deal of this work of denudation was produced by the retiring diluvial waters: and that this agency operated since the present levels of the surface were attained.

Notwithstanding the preceeding reasoning, I confess that I cannot entirely get rid of the suspicion that Mount Sugar Loaf and Toby, especially the latter, may have been thrust up above the general level of the formation by an internal force. I have attempted to show that the valley of the Connecticut is a valley of subsidence. Consequently a fault passes through it, and possibly there may have been vertical movements along some parts of the fault, since the consolidation and general elevation of the strata. Still, all my examinations of the strata on Sugar Loaf and Toby rather oppose such a supposition.

The situation of this valley, when this mighty work was performed, must have been very different from what it is at present. Probably much of the denudation was made while yet the the whole country was beneath the waters of the ocean; and by the waves along the shifting coast, as it emerged at different periods from the deep. Whatever currents of water may have since swept over the land, have also aided in the work; as have most of the rivers which now traverse this valley. But this subject will be more fully illustrated in the subsequent parts of my Report.

## *Valleys of Berkshire.*

That the valleys of Berkshire were commenced by the original elevation and dislocation of the strata is most probable. But there is one circumstance that seems to point to ordinary disintegration and running water as powerful agents in their modification. The general strike of the strata in that part of the state, corresponds to that of the mountain ridges; which is north several degrees east, and south several degrees west; while the dip is towards the east, and usually large. These rocks consist of talcose and mica slate, quartz rock, and gneiss, which are interstratified with white and gray limestone. *But the limestone appears only in the valleys.* The steep and lofty mountain ridges are all composed of slate rocks; except that sometimes we see the limestone near the foot of their western sides, passing under the mountain. I tried long to convince myself that the limestone was a later deposit than the slate, made in the valleys between the ridges. But the frequent examples of interstratification of the limestone and slate, which I met in all parts of the county, showed this theory to be untenable. The hypothesis then to which we seem driven, is, that since the limestone is most easily worn away, disintegrating and eroding agencies have more rapidly removed that part of the surface where this rock predominated, until valleys from 1500 to 2000 feet deep have been produced: while the harder parts, composed of slate, although extensively worn down, still stand out in Alpine relief! Almost every where we see examples of this process on the surface of rocks exposed to the weather and currents of water, viz.: the formation of furrows

in the softer parts, while the harder parts remain in ridges. But when we see the work on so immense a scale as in Berkshire, we hesitate to refer it to the same cause, in part probably, because in spite of all that has been said of late about the long periods required for geological changes, the mind finds it difficult to conceive of a duration so long as would be requisite for such a work. Yet I do not see but the conclusion is forced upon us, not indeed as a demonstration, but as a probable inference, that these valleys must have been formed in a good degree by denudation. Let any one who sees nothing of grandeur and sublimity in the facts and reasonings of geology, take his stand upon one of the highest ridges of Berkshire, and attempt to explain the origin of the valleys and hills around him: and whether he impute them to existing agencies, operating as they now do, or conceive of the whole region long enough beneath the sea to have the work accomplished by its currents, or imagine the action of mighty deluges, or even go back to the original elevation and dislocation of the strata, surely he must confess that the thoughts, reasonings and conclusions which are forced upon him, are of a most magnificent kind. And it is such thoughts that give an interest to geological researches in almost every part of the earth. Geology does not consist in being able to name and describe specimens of rocks and fossils, and refer them to their proper place in artificial systems: but more eminently, in being able to reason correctly from facts, and to form adequate conceptions of phenomena and revolutions, on a scale so immense as to sink into comparative insignificance all the natural changes on the earth which occur in the experience of an individual. A man who can collect and correctly describe rocks and fossils may be very useful, but he only who can rightly estimate and apply the dynamics of nature so far as they are understood, deserves the name of a philosophical geologist.

### *Denudation in the Eastern part of the State.*

It is my belief that denudation has been quite as powerful in the eastern, as in the western, or central parts of the state: but the proof is less striking. The quantity of detritus, however, is most abundant in the eastern section: but the mountains I fancy have been mostly swept away; except such a ridge as the Blue Hills: which like the sienite of Cape Ann and Cohasset, has survived the wreck, because of its extreme hardness. Of other rocks one meets with only occasionally a low outlier, whose general form indicates powerful erosion in times past. I fancy that the several patches of what I call graywacke were once united into a continuous formation across the whole state. But I can offer no decided evidence on this point.

What shall we think of so remarkable an outlier as Wachusett Mountain.

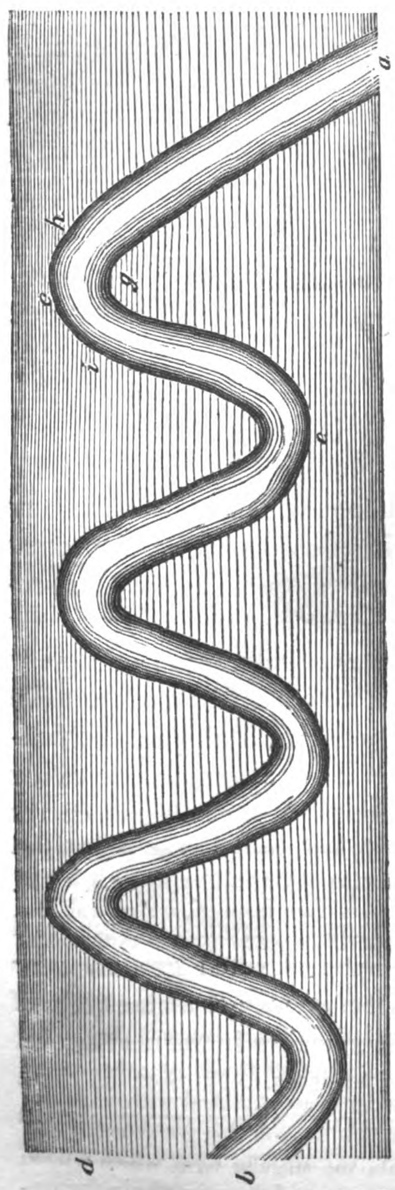
and of Monadnoc in New Hampshire? Did the strike and dip of their strata differ from those of the rocks in their vicinity, we might suppose them upheaved by a local internal agency. But I have not found any evidence of such a disturbance. All the evidence is the other way; while there is striking proof of powerful denudation on their summits. Shall we then suppose that the whole gneiss formation of Worcester and Middlesex counties was once as high as the present summit of Wachusett and Monadnoc? and that it has been subsequently eroded to the depth of nearly 2000 feet; while the only evidence of its former existence is these eminences? If such was the fact, why were these mountains spared by the denuding agency? for their strata do not appear to possess any peculiar power of resistance. I confess myself unable satisfactorily to answer these enquiries. When I look at the subject in one aspect, I incline to the opinion that the hypothesis of denudation is the true one: Yet it has great difficulties. I do not think, however, that the vastness of the work, and immense period requisite for its accomplishment, ought to be regarded as one of these difficulties. For in the present state of geological knowledge, who can determine when these denuding processes commenced, or to what depth they have sunk the surface of our continents?

## *Serpentine Course of Rivers.*

When we find the bed of a river in a mountainous or rocky country very crooked, we see at once that the current has been compelled to change its course by the obstructions which alternately opposed themselves to its progress upon the sides. But it would be natural to infer, that when a river runs through a level alluvial region, where the soil offers equal resistance in every part, it would pursue a strait course: yet in fact we often find streams to be more sinuous in such circumstances than in any other: and often the flexures are remarkably uniform in size and shape. It becomes an interesting enquiry, whether there is not some general law by which such elegant curves are produced, that have always been the admiration of the lover of fine landscapes. Perhaps the best example of this sort to which I can refer in Massachusetts, is near the mouth of the small stream passing through Saugus, and emptying into the ocean at Lynn. Standing upon elevated ground near Saugus Meeting House, and looking down the stream, we get a fine view of the numerous and graceful curves, which this river makes in the nearly level and apparently uniform marsh, through which it passes. A part of these curves are shown in Plate 9; as already described. They occur also in other streams in the state: and have so much resemblance among themselves, that I have long suspected the operation of some general law in their forma-

**tion; and have felt dissatisfied with the explanation usually given of sinuous rivers, that they result chiefly from the unequal hardness of the materials which they excavate. But what other principle to call in to explain such cases as I have described, I confess myself at a loss to determine: and I have found no light on this point among geological writers. I take the liberty to make a few suggestions on this subject, which, though far from being satisfactory to myself, may lead others to examine it with more success.**

Fig. 53.



In the case which I have stated above, viz. where small streams pass through level alluvial deposits, it is obvious that the stream must have formed its own bed; and probably also it deposited the alluvium through which it flows; or nearly all of it. Let us then suppose the surface beneath the alluvium to have once formed a shallow valley, whose sides rise but little, and whose surface is very uniform, as is shown in Fig. 53: such a valley as would be produced by a larger stream running strait through it. Suppose now a small stream, *a*, *b*, to enter this valley obliquely, at *a*; and that the bottom was covered with a thin layer of mud, in which the water would at once form a shallow bed. It would proceed towards the opposite side, until arrested by the gently rising bank, as at *c*. This would turn the current down the valley towards *d*. But the question now occurs, whether it would proceed directly towards *d*, or be turned more or less towards the opposite bank, as at *e*. It is obvious that the bank at *c*, by changing the course of the stream, would check the current more on the side *g*, than on the side *h*; and consequently, the suspended matters in the water would be deposited more abundantly along the shore near *g*, than near *h*, so that a bank would begin to be formed at *g*; whereas at *h*, the bank already existing, would be more or less worn away. But the force of the current would be so deadened after passing *c*, that it would wear away less between *c* and *i*, than between *c* and *h*: consequently, the stream would be turned more and more towards *e*, as the bank between *c* and *h* was more and more worn away. The check also, which the current would receive at *c*, would cause it to deposit sediment at *i*, and beyond, so that erelong a bank would be formed on that side across the whole valley: while occasional freshets would at length equalize the alluvial deposit over the whole valley, except that the stream would rarely be diverted into a new bed. If now it be admitted that the current might in this manner be deflected towards e, in a similar manner would it be turned back again beyond e, and thus would it make curves alternately

to the right and left, while the valley continued favorable for the work. But if it met with any unusual obstruction, the regularity of the curves would be impaired; as is the case with most rivers. Near the coast also, the action of the tides would probably somewhat modify the effects above pointed out.

## *Anomalous Effects of Water.*

Under this head I shall describe a few *lusus naturæ,* which I have met in the State, where water was the agent.

A few rods below the bridge in Zoar, shown on Fig. 21, a large rock projects from the north shore, having its outer extremity perforated by a large opening as shewn on Fig. 54.

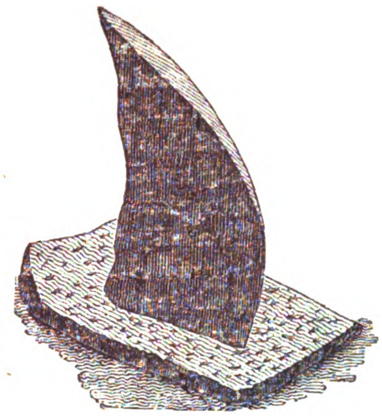
Fig. 54.

*Arched Rock: Zoar Bridge.*

The height of this rock at low water, is as much as 12 or 15 feet; and it projects from the shore in such a manner that the stream has a fair chance, by means of the pebbles which it brings down, to make curved excavations in it. In one place it has worn quite through, as shown above. But probably ere long the outer pillar on which the arch rests, will be made to yield to the same agency.

Another *lusus* is shown on Fig. 55. Its base consists of a slab of granite, 2 1-2 inches thick, 10 inches broad, and 20 inches in length. To this, near its center, is firmly attached perpendicularly, a bladed tapering column of coarse micaceous limestone, 2 inches thick, 10 inches broad, and 26 inches long. It was found loose in a mountain torrent in Conway. And without doubt, the base once formed a vein in micaceous limestone. Probably a mass of this got detached and exposed to the erosive action of the water, which wore it into the singular form which it now exhibits.

Fig. 55.



*Lusus Naturæ.*

Fig. 56 represents a mass of mica slate worn into a singular shape, which I found on a branch of Westfield River, near Falley's Cross Roads in Chester. The stratification of the slate is at right angles to the axis of the block; and the different layers being of very unequal hardness, the water has worn away the softer ones more than the others.

Fig. 56.

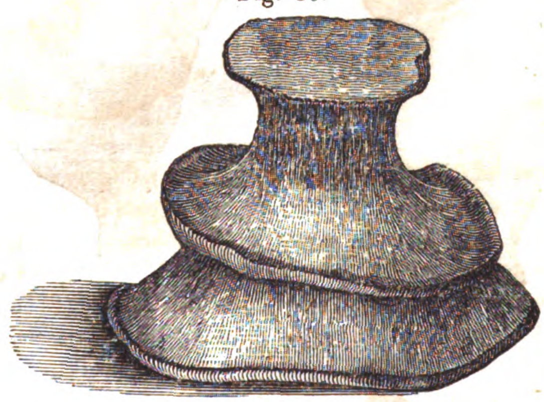


Fig. 57 shows a remarkable imitation of a boot, or rather of a man's leg and foot. It is a mass of rather coarse limestone: and one perceives on looking at it, that human art has had nothing to do in its formation; but that water alone has carved it out. Its diameter at the top is 4 1-2 inches: at the ankle 3 1-2 inches. Height from the hollow of the foot, 12 inches. Length of the foot, 9 inches. These dimensions, it will be seen, correspond very well with those of a man's leg of ordinary size. And scarcely a protuberance or depression exists in a real leg and foot, that is not found in this stony one. This is, however, considerably more flattened than a real leg; but this scarcely affects a side view. The specimen is in the collection of Mr. Anthony Clarke of West Stockbridge, who permitted me to take a drawing of it. It was obtained in that vicinity, and was for several years used by a shoemaker for a sign.

Fig. 57.

*Pseudo-fossil Boot.*

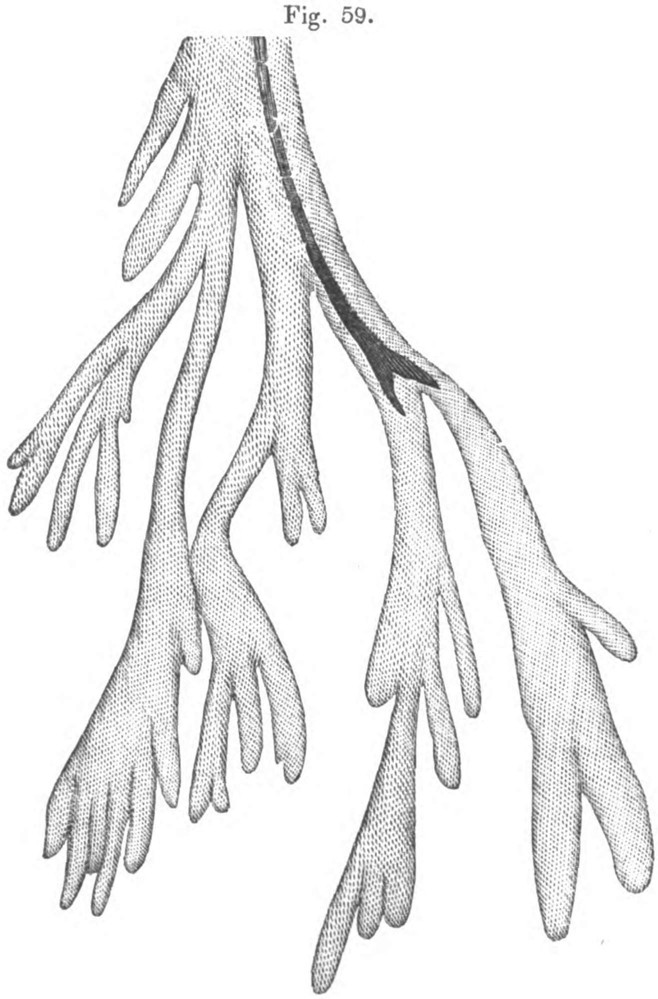
Fig. 58 represents a mass of limestone, less than a foot high, dug up a few years since in Northampton, and worn into such a shape that it would be easy to pass it off among those unacquainted with geology, as a petrified animal, sitting upon its haunches. But it is only a mass of Berkshire limestone, which water has transported over Hoosac Mountain, and worn into this imitative shape. The specimen is in the College Cabinet at Amherst.

Fig. 58.

*Pseudo-fossil Animal.*

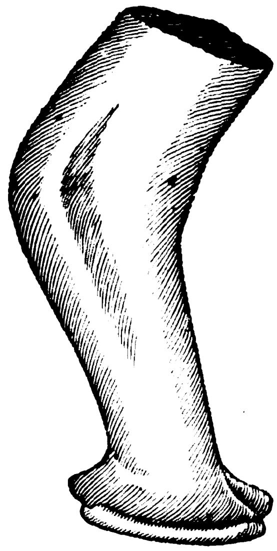
Fig. 59 exhibits the curious effects of water trickling down an inclined sand bank in Russell, on Westfield river. The sand was of a rather coarse sort, and nearly saturated with water, so as easily to be slid down an inclined plane, by the addition of a little more water. As it worked downward, instead of continuing in one ridge, it ramified, as is shown in the drawing. Could sand, brought into such a condition, be covered with other materials without destroying its shape, and then the whole be hardened into a rock, it might perhaps be mistaken for an organic relic: and possibly this case may explain some examples of concretionary structure in the fossiliferous rocks: though I have never seen any thing like it. Since taking the sketch here given, I have met with the same phenomenon in Sunderland: and in one or two other places. But it is not common.

Fig. 59.



On Fig. 60, we have represented a water worn mass of sienite from Northampton, which in size and shape a good deal resembles the leg of an ox. Like that it is flattened, and a depression exists just below the joint. The hoof, however, is somewhat too large. The specimen is in the Cabinet of Amherst College.

Fig. 60.



On the floor of the limestone cavern at Baker's quarry in Lanesborough, already described, I found a singular concreted deposit, not from the dripping of water from above, but from the water that collects in the low places, and is charged with carbonate of lime. As the water evaporates, the lime is deposited, often to the thickness of three or four inches: and its surface is disposed in sinuous and fantastic ridges, while the under side of the deposit is still soft and pulverulent. Plate 18, Figs. 1 and 2, will give a good idea of fragments broken from this deposit. It is easy to see how limestone might be deposited in such a place from water holding it in solution: but not easy to explain the peculiar mode of its occurrence. I cannot conceive how currents of water, even if we admit their existence in such circumstances, could produce the remarkable shapes of these deposits; and am compelled to refer it to chemical agency. If this be admitted, it must be regarded as an example of concretion. But it must be a concreted structure of a *sui-generis* character.

The most interesting aspect in which these concretions can be viewed, is their application to the explanation of certain curious concretions in the fetid limestone of West Springfield; which I was formerly disposed to refer to organic agency. But I will not go into details here. I shall bring up the subject again when treating of red sandstone.

Nos. 2504 and 2505, which are arranged under alluvium in the State Collection, are specimens of these concretions.

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## 2. DILUVIUM, OR DRIFT.

I shall probably be thought by some, either ignorant of the present state of geology, or unreasonably tenacious of former opinions, by retaining the term *Diluvium*, to designate that coating of gravel, sand, and clay, covering the surface almost everywhere, and resulting from aqueous agency between the deposition of the tertiary and alluvial strata. By doing this, I do not intend to advocate the opinion that all this deposit was the result of one transient universal deluge. But in New England, the greater part of it certainly appears as if the result of powerful currents of water, rushing over the surface in the manner of a deluge. So that in this country, diluvium can hardly be a misnomer. Yet this is not my reason for retaining the term. I retain it on the following grounds. Notwithstanding the efforts of some distinguished geologists to expunge the diluvial formation from the geological series, the decision of a large majority of geologists, as I apprehend, is, that for the present at least, it must be retained. To strike it from the list of North American rocks, would be to dispense with the most remarkable member of the series. 2. All the substitutes that have been proposed for that of Diluvium, such as "Erratic Block Group," "Bowlder Formation," "Detrital Deposits," "Drift," &c. seem to me to be as deficient in signification, and to convey as erroneous notions as the term Diluvium, which in euphony certainly takes the precedence. 3. Probably no part of geology is in a more unsettled state, or more imperfectly understood, than that of diluvium: and while it continues so, a designation for the formation is of little consequence, provided observers describe accurately what is included under it. When the exact limits and theory of the formation shall be settled, an appropriate name can be easily applied to it.

I have intimated that the limits of this deposit have not been certainly fixed. In general we find it spread irregularly over every other formation but the alluvial. But some deposits in Massachusetts, which I had formerly supposed to belong to the newest tertiary, I now place under diluvium; and a similar disposition of some supposed tertiary beds has been made in Europe. On the other hand, I find it still more difficult to separate diluvium from alluvium in some cases; though the general characters of the two formations are very distinct.

I do not include under diluvium the tearing up, rounding, smoothing, and comminution, of the bowlders, gravel and sand, that now compose it: although without doubt a part of these processes must have been performed during the diluvial period. But probably a large proportion of this work was accomplished by aqueous agencies, previous to that more powerful one

which we denominate the diluvial. That agency I suppose brought these materials, previously in a measure broken up and rounded, into their present state. And yet I do not suppose this agency to have been a very transient one. For I hope to present evidence soon of its long continuance as well as great power.

Of all the formations probably diluvium is the most difficult to study. A man may obtain some tolerable idea of the general geological features of a country by passing through it once or twice. But no transient traveler can tell us much of its diluvial phenomena. In order to do this, he must first become accurately acquainted with all the older formations and their limits. Else when he finds pebbles and bowlders drifted from their parent bed, how can he be certain of the direction in which they came? It is now at least twenty years since I began to examine Massachusetts geologically; and ten years since I commenced exploring the whole state. No year has passed in which I have not accumulated many facts respecting diluvium; for which I have always kept an eye open. The great number of these facts which I shall here present, will at least show I think, that the general conclusions at which I arrive, have not been formed hastily, and without broad premises. Those who will take the trouble to compare the present with my former reports, will see that those general conclusions have not been altered since they were first announced: and that the additional facts which I now give, only serve to render them firmer. Whatever corrections future observers may be obliged to make in my statements, I feel quite sure that they will never doubt that the diluvial waters in Massachusetts took a direction between south and southeast; and that they have left upon the solid ledges innumerable furrows and scratches, as proofs of their direction and great power. These are the most important results at which I have arrived; and they are entirely independent of hypothesis. When first announced, the latter statement especially, respecting grooves and scratches, was received I believe by the ablest geologists of our country with strong scepticism. But I doubt whether all of them have not ere this seen enough of such phenomena in other parts of the land, to be satisfied that I have stated only the truth: if I may be allowed to form an opinion from the numerous annual Geological Reports that have appeared in different parts of the country within a few years past; and from several articles in the scientific journals. In some instances the direction of these grooves varies considerably from those in Massachusetts: but I speak now only of their existence. And as I have been obliged to bear the obloquy of stating what was thought to be erroneous, I trust I may claim the honor, if there be any, of first calling public attention in this country to an interesting geological phenomenon.

*Vertical Limits of Diluvium in Massachusetts.*

In general terms, this deposit may be said to lie between the tertiary and alluvial strata. But it seems quite probable that some finer deposits of clay and sand, which were produced during the same geological period, have been referred to the tertiary strata. In my former Report I described certain horizontal deposits of blue clay, covered by layers of sand, occurring in limited deposits in the state, especially in the valley of Connecticut river, as belonging to the Newest Tertiary: because I had no evidence that the diluvium passed beneath it. But since that time, I have discovered several sections, recently made, which render it almost certain that this Newest Tertiary constitutes a part of the diluvial deposit:—usually its upper part: but sometimes interstratified with it: as in Fig. 65, which will soon be exhibited, and which is a section in diluvium. Wherever valleys of any considerable extent existed in the state at the period of diluvial action, and these were cut off from the ocean by some barrier, I find this clay and sand. I infer that it was deposited by the retiring diluvial waters; though I undertake not here to decide whether those waters retired in consequence of the subsidence of the ocean, or the elevation of the land. I shall present evidence that in some parts of the state, this draining of the waters occupied a considerable length of time: and probably left large expansions of the rivers or lakes, which were not drained for centuries, or until the streams at their outlets had worn down the barrier. This process I should call an alluvial agency: and I consider the diluvial agency to have ceased at the point when the effects can be explained by existing agencies, operating with their present intensities.

The only other strata in Massachusetts which can be regarded as tertiary, is the formation on Martha's Vineyard, which I have considered in former Reports as the equivalent of the Plastic clay, or lower portion of the Eocene strata in Europe. On the Vineyard these strata, which are highly inclined, are covered over with diluvium: but I have no evidence that any diluvial deposit is beneath them. Hence, were we to confine our attention to Massachusetts alone, we should have the whole period from the deposition of the Plastic Clay to that of Alluvium, in which diluvium might have been in the course of formation. But the mere fact that Plastic Clay is covered by bowlders and gravel does not show that the deposition took place immediately after the production of the Plastic Clay. And the fact that the latter has its strata inclined, is a presumption that there was an interval between the two events; perhaps a long one: while on the other hand, the intimate connection between the diluvial and alluvial deposits, makes it probable that no interval could have come in between them.

In thus including regular layers of sand and clay in diluvium, I am not without precedents. In 1835 Rozet described diluvium as consisting of clay sand and gravel, with bowlders arranged nearly in the same order as I suppose to exist in Massachusetts generally, viz. the sand highest; the clay next lowest; and at the bottom, the gravel and bowlders. (*Traite Elementaire de Geologie par M. Rozet, Tome* 1. *p.* 256.) Rev. W. B. Clark, in a paper read before the London Geological Society, March 5th, 1837, on the Geology of Suffolk, in England, describes a bed of clay in the diluvium 400 feet thick: and specimens which I received from that gentleman cannot be distinguished in appearance from the diluvial clay of Massachusetts. Very similar are specimens recently received from Italy. Dr. Forchhammer supposes the "Bowlder Formation" of Denmark to have been "one very long series of alluvial deposits, extending from the plastic clay group beyond the ordinary diluvial epoch." Professor Phillips suggests, also, that perhaps the plastic clays and sands of London and Paris, ought to be thus regarded. (*Treatise on Geology, Vol.* 1. *p.* 297.)

### *Lithological Characters.*

These have been partially stated: but the whole need to be given. 1. *Bowlder Stones or Erratic Blocks.* How large a rounded and transported block of stone must be in order to make it a *bowlder*, seems not to be exactly settled. But in Massachusetts the amount of them that are of great size is so large, that we need not reckon those of doubtful character. These bowlders form one of the most striking objects in the landscape in many parts of the state, and scarcely no part is free from them. 2. *Gravel and Sand mixed together confusedly.* These constitute the great body of diluvium; and are composed of every variety of rock found in the state, and of some varieties found in place only beyond its limits. The softest kinds of rock, however, have been mostly reduced to sand or clay; and the great mass, both of bowlders and pebbles, consists of the most unyielding of our rocks; such as quartz, porphyry, sienite, greenstone, gneiss, mica slate, and granite. Thus, in the region west of Connecticut river, while masses of the quartz rock of Berkshire county are met with at almost every step, it is very rare to meet with a fragment of limestone at the distance of more than half a dozen miles from the limestone deposits; although a glance at the geological map will show, that the latter occupy much more of the surface in Berkshire county than quartz rock. 3. *Beds of Clay.* This clay is usually of a blue color, but becoming nearly white in those parts of the state where a great deal of feldspar is contained in the detritus. In all cases, however, this diluvial clay abounds in the protoxide of iron. It is not of much use except for making

bricks, and common red earthern ware. Ususually it occupies basins, or trough shaped cavities, and must have been deposited in quiet waters; as neither bowlders nor gravel are usually mixed with it. Frequently, however, as along the sea coast, its deposition is confused, and sometimes (ex. gr. at Fitchburg, west end of the village,) pebbles are mixed with it; and sometimes (as on the rail road cut in the south part of Palmer,) even quite large bowlders. 4. *Consolidated sand and pebbles.* In some instances the hydrate of iron acts as a cement of diluvium; but the rock thus produced is easily crumbled down. Carbonate of lime, however, in some localities, has formed a conglomerate of considerable tenacity. The calcareous diluvium which is not uncommon in Springfield, West Springfield, and South Hadley; and which has been particularly described in the first part of my report, is sometimes very firm; though on exposure to the weather, it at length crumbles down; and therefore can hardly answer for any purpose of construction. No. 1560 is an example of this rock.

In Pownall, Vt., three miles north of William's College, is an unique and interesting example of diluvium. It lies on the eastern side of Hoosac river, against a hill of mica slate; and rises at least 100 feet. It consists of pebbles of quartz and micaceous and argillaceous slates, from three to four inches in diameter, down to coarse sand: and a part of the mass is consolidated into conglomerate and sandstone. (Nos. 25, 26, 27, and 28.) The cement is carbonate of lime; which having been dissolved in water, has been diffused uniformly through the mass. It is not perceived by the eye; but on applying acid, a brisk effervescence ensues; and hence I infer that it was infiltrated in a state of solution. And although I could perceive but few fragments of limestone among the diluvium, yet as the whole region abounds in this rock, it is hardly possible that it should not exist there, at least, in the state of sand. This being admitted, the consolidation of this stratum is easily explained by causes now in action. I ought to add, that when thus forming solid masses, it is as distinctly stratified as are most of our secondary sandstones and conglomerates.

How common may be consolidated diluvium in this country, I cannot say. But no account of any other locality except the above has fallen under my notice. In Europe, geologists describe a similar rock, if Brongniart's *Terrains Clysmiens* is synonymous with diluvium; for he says that 'the parts of the rocks of that class are sometimes united by a base or cement chemically produced; that is by solution.'* At any rate, the consolidated shingle bed, described by Mantell in his Geology of Sussex, as occurring at Brighton, in England, must be regarded as of the same character as that in Pownall above described.

5. *Beds of Sand.* This sand is siliceous and varies from very fine to quite coarse; the latter usually lying at the top. The beds of this sand are almost invariably spread over the beds of clay, not only in Massachusetts, but in other parts of the country which I have visited: and so common is the fact, that where we find clay, we expect to find over it layers of sand, unless al-

* Tableau des Terrains, p. 66.

luvial agency has removed them. I cannot but infer, therefore, that these siliceous deposits resulted from some general agency; and I cannot conceive that any cause now operating with its present intensity could have produced them, and therefore refer it to diluvial action. 6. *Limonite, or Hydrated Oxide of Iron.* This I have found among diluvium only in Berkshire County and in the eastern part of New York. And there it is a diluvial product in no sense except that diluvial action has torn it from the beds of this ore that project from the strata of mica and talcose slate. I have not seen in the state any example of a deposit of iron ore during the diluvial period worthy of notice, although we frequently meet with pebbles coated and sometimes cemented by hydrate of iron, and probably some of the deposits of yellow ochre belong to this period.

### *Stratification, Inclination, and relative position of the varieties of Diluvium.*

That the clay and much of the sand which I have included in this formation, are stratified, will admit of no question by those who have seen good sections through them. But some have an impression that what is usually called diluvium, viz. gravel and bowlders, was thrown together in such utter confusion, as to exhibit no sorting of the materials and no parallelism of arrangement. And the usual aspect of diluvial hills, seeming to be a mere promiscuous mass of gravel and sand, is apt to confirm this idea. But when a fresh section is made through such hills, and through the formation generally, I have rarely failed to discover as distinct marks of stratification as in the older fragmentary rocks equally coarse. In fact, I cannot conceive how detritus could be deposited in water the most violently agitated, without separating in some measure into portions more or less coarse: and this is nearly all the stratification which diluvium exhibits. It is sometimes made more striking by some of the layers being a good deal more ferruginous than others: but rarely by any thing like a seam separating them: and the same thing is usually true of the coarsest conglomerate. The sections which I shall shortly present show the extent to which it is stratified.

As a general fact, the stratification is horizontal; or as much so as in any deposit made from water. This does not preclude the idea that the layers are often highly inclined in particular places. For it is a dip extending through the whole, or a large part of a formation, that proves the formation to have been tilted up since its deposition. Even if this does not exceed a single degree, it can in few cases be ascribed to original deposition. But clay, sand and gravel, may lie inclined at an angle of 5°, 10°, 20°, or even 30°, in particular spots, and the dip be accounted for by its having been deposited on an originally inclined plane. Some sections of this sort I will now introduce.

Fig. 61 is a section nearly 4 rods long, and 20 feet high, in diluvial sand and gravel; the former rather predominating. The spot is situated at the mouth of a small stream on the bank of Connecticut river in Montague, at Cobb's Ferry. Although the stratification is here not very regular, nor entirely continuous, yet it is obvious, and we see great irregularity in the dip. We also see towards the lower part, that the general stratum is more or less divided obliquely by fine minor layers, which have quite a dip. This is a most uncommon appearance in our diluvial deposits; and it may be explained, as may also the general dip in the following section, by supposing the gravel and sand urged forward by general and eddy currents into deeper water, over slopes already formed more or less steep.

Fig. 61.

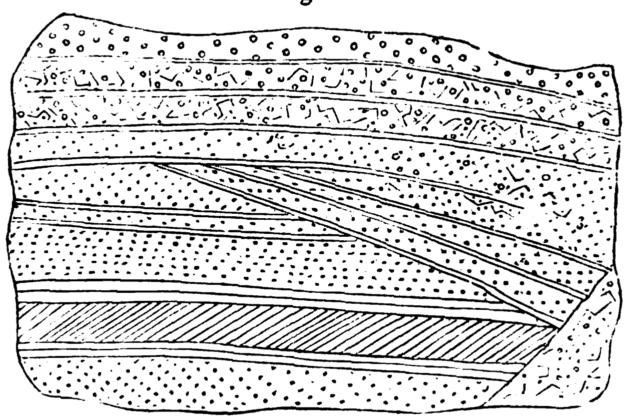
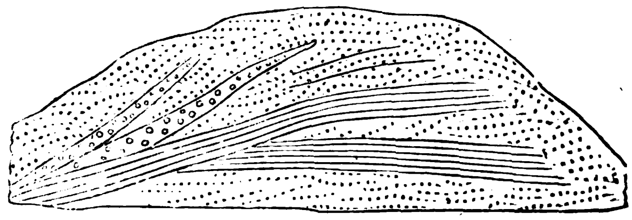


Fig. 62 is an analogous section in Uxbridge, two miles south of the central village. It is 5 rods long, and 8 or 10 feet high; and exhibits great irregularity in the position of the layers, as well as in their degree of fineness. In this respect, the materials vary from very coarse gravel, to common sand. The spot is on the principal road leading towards Providence.

Fig. 62.



Near the bottom of the deep valley, one mile southeast of the village of Barre, I found the section shown on Fig. 63. It is a good example of what is called *false stratification*; that is, a sub-division of the principal layers into fine laminæ, oblique to the planes of stratification. The materials are sand and gravel.

Fig. 63.

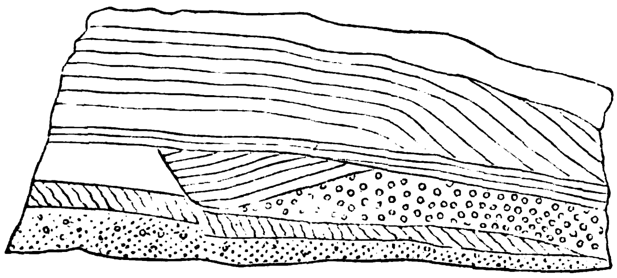


Fig. 64 is a similar section in Amherst laid open by an excavation for a road one mile east of the east village. It is only a few feet in length and height and the materials are sand and rather fine gravel. But some of the layers have a greater dip than I have seen elsewhere, and greater than I should suppose possible to have been produced by deposition. Yet there is no other plausible mode of explaining the appearance.

Fig. 64.

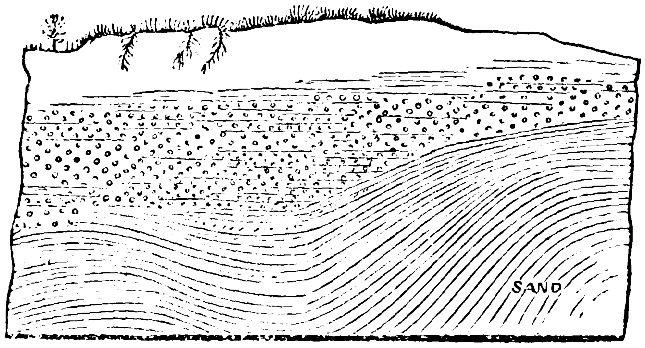
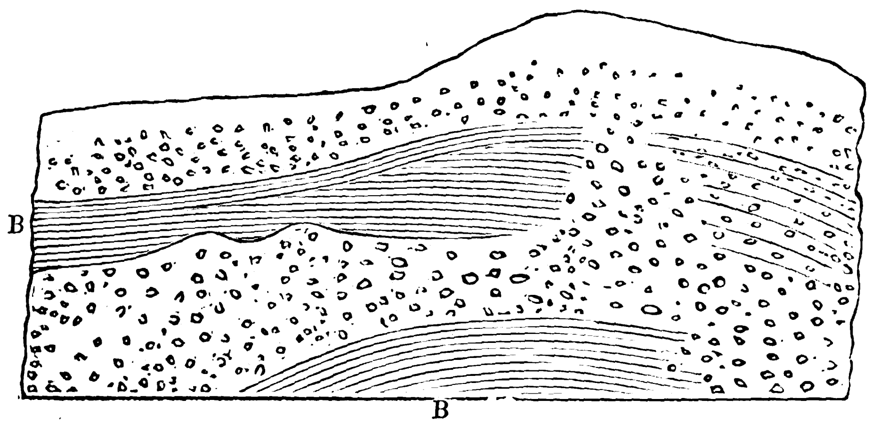



Fig. 65 is a very instructive section, which was laid open in the south part of Palmer, by a deep rail road cut. It is more than 20 rods long, and in some places at least 50 feet high. B, B. are layers of fine clay (No. 205*b*,) nearly horizontal; the upper stratum of which terminates laterally, as if resting against the slope where it was originally formed. In the upper part of the clay, pebbles and even large bowlders are sometimes seen mixed. This clay is of a light blue color, and very much resembles all the diluvial clay in the central parts of the State. The sand and pebbles, that lie above and below it, are unusually coarse; some bowlders several feet in diameter being mixed with them. In general, the stratified character of this mass is scarcely discernible: But near the eastern side of the hill, it becomes quite manifest; and here the layers have an easterly dip of not less than 25°.

Fig. 65.



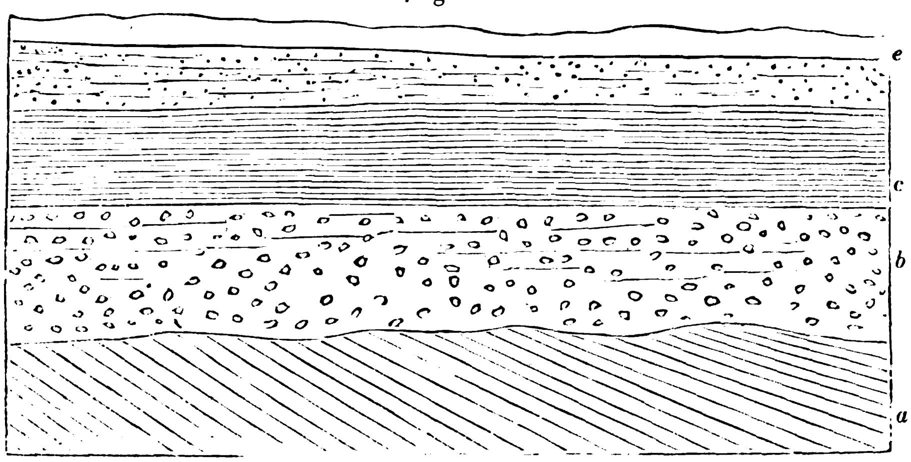

*Section on the Western Rail Road: Palmer.*

I will not stop here to make formal theoretical inferences: yet I can hardly avoid saying, that such sections as the above, render it almost certain, that there must have been periods of intermission of the violent agitation in the waters by which our diluvium was accumulated; so much so, as to allow of the deposition of clay. For I cannot conceive it possible that the layers of clay, imbedded in the gravel, could have been transported from some other place. A similar section may be seen in the high cliff along the eastern bank of Connecticut river, a mile south of

South Hadley Canal, just within the bounds of Springfield. Here the clay lies near the top of the cliff; and a vast amount of fine detritus mostly from the sandstone, lies beneath it. I give no drawing of this place, because it did not come under my notice till its face was partially covered by clay and sand, washed over it by rains: so that although the above stated facts are quite obvious, the true character of the whole cliff cannot be given. And I would here say, that in almost every case, unless I have happened to see excavations immediately after they were made in diluvium, and before powerful rains had intervened, their character has become too obscure for taking a sketch; and I doubt not that the sections I have given above, are by the present time entirely obliterated.

The excavation for the Western Rail Road on the north bank of Agawam river, for three or four miles west of the village of West Springfield, presents us in several places with a very satisfactory section of the relative position of the strata under consideration. Where they are undisturbed, they present the order shown upon Fig. 66. *a* represents the strata of shale and sandstone having an easterly dip; *b* a deposit of calcareous diluvium: *c* a deposit of clay, the lower part of which is often full of small pebbles: *d* a deposit of sand: and *e* the vegetable mould that covers it. The diluvium is usually the thickest stratum, above the sandstone.

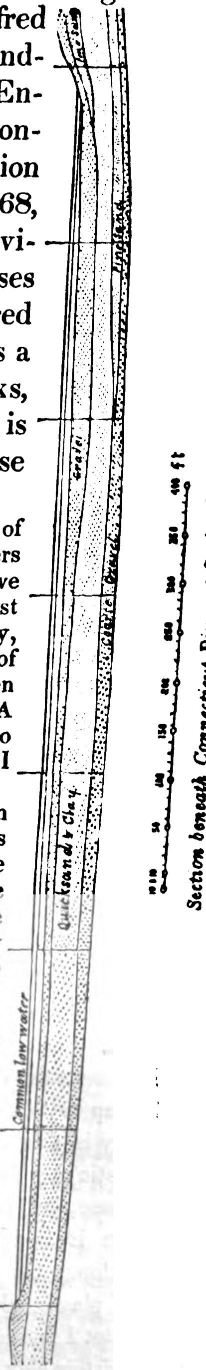
Fig. 66.




*Section on the Rail Road, West Springfield.*

One of the most satisfactory Sections in the valley of the Connecticut, has been obligingly furnished me by Major Whistler and Captain Swift, principal Engineers on the Western Rail Road. In order to ascertain whether they could trust the bed of Connecticut river at Springfield as a foundation for a viaduct, over which the Rail Road might pass, they had borings executed to the depth of 60 or 70 feet beneath the surface of the water, and 50 feet below the bottom. As will be seen from the section on Fig. 67, a deposit of sand and gravel, such as usually constitutes the bed of the river, was first penetrated: next a deposit of quicksand and clay; and beneath this, a deposit of coarse gravel with bowlders. This probably is the principal diluvial coat in this valley The clay over it is rarely more than 30 feet thick. The perpendicular lines upon the section, mark the spots where the borings took place; and where the abutments will be constructed. The gentlemen mentioned above, have also furnished specimens of the gravel and clay, obtained from these excavations, which will be found in the State collection; and a more particular account of their situation will be given in the descriptive Catalogue at the end of this Report. It is an interesting fact, that all the clay found in the bed of the river at this place, is calcareous.

Fig. 67.



*Section beneath Connecticut River at Springfield.*

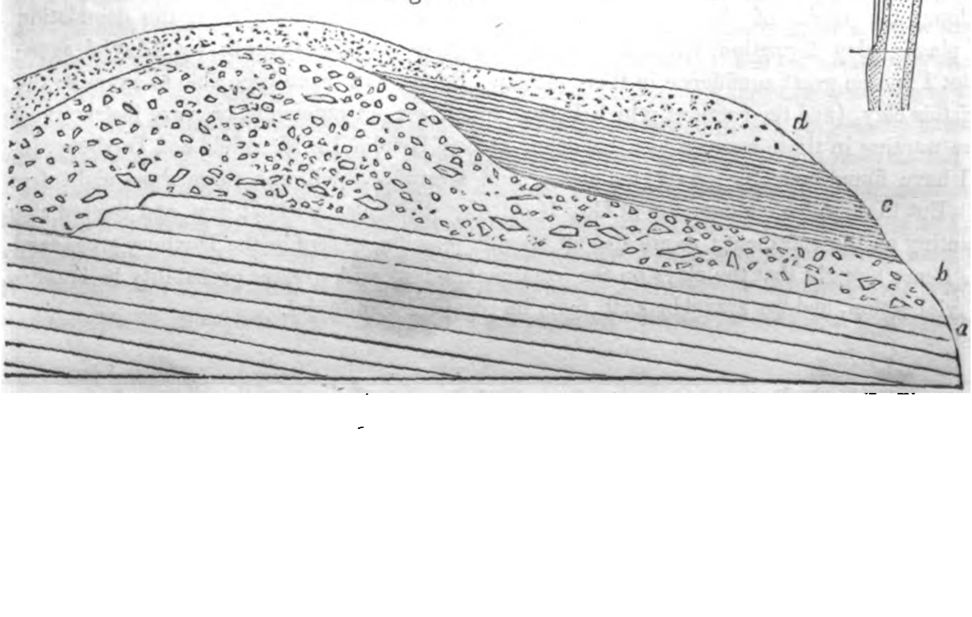
In Vol. XXII of the American Journal of Science, Alfred Smith, Esq. has given a section of the strata above the sandstone, as they were cut through in excavating the canal at Enfield Falls in Connecticut; which I insert, because it confirms the views which I have exhibited of the relative position of the clay and diluvium along Connecticut river. On Fig. 68, *a* is the red sandstone slightly inclined; *b* a stratum of diluvium, containing fragments of the sandstone, and rounded masses of granite, greenstone, and other foreign rocks mixed with red clay: *c* is a layer of clay of the same reddish color: *d* is a coating of earth, with fragments of the same foreign rocks, though finer: Hence I infer that even the upper deposit is diluvial, since it is difficult to account for the presence of these rocks in any other way.

In the pure clay beds the dip is rarely as great as in some of the cases of sand and gravel pointed out above. Indeed, except in a few spots, the layers are absolutely horizontal. A little east of the Academy in Deerfield, as we ascend the hill, we perceive a westerly dip, not more than 5°. On the east side of North Sugar Loaf Mountain in the same town, the dip is easterly, nearly 10°. In Brattleborough Vt. I noticed as high a dip one mile south of the east village. On the old road from Amherst to Hadley, the clay is seen to have a gentle undulation: but never producing a dip of more than 5°. A little north of Cabotville, however, on the east side of the stage road to Chicopee, I noticed the clay dipping nearly 25°; which is the largest dip that I have seen: and very likely this might have been produced by a slide.

In the western part of West Springfield, an excavation for the Western Rail Road is made through a ridge of greenstone and sandstone. Upon its south eastern side we find the layers of clay arranged as shown upon the Section in Fig. 69. The greenstone evidently formed the shore when the clay was deposited, which conformed at first to the rather steep slope of the rock: but as the bottom was more and more filled up, the layers gradually approached nearer to a horizontal position. *a* represents the sandstone; *b* the greenstone, and *c* the clay.

The layers of our diluvial clay rarely exceed half an inch in thickness in the valley of the Connecticut. In each layer the coarsest part of the materials is invariably placed at the bottom; and there is a gradual diminution of fineness upward, until at the top it is exceedingly fine clay. This arrangement is just as we might expect from deposition in

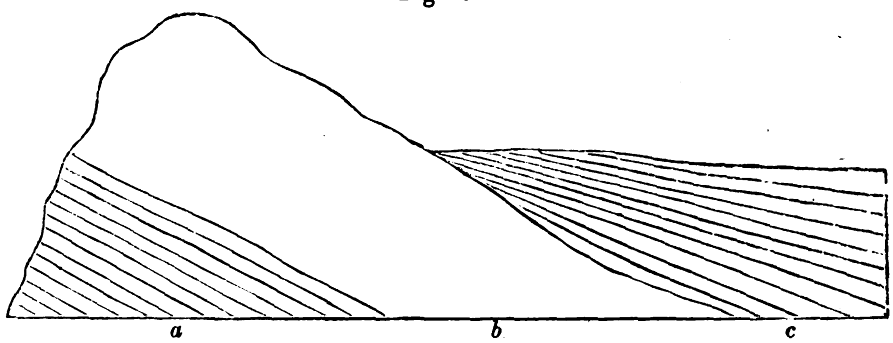
Fig. 68.



water; and it shows perfectly quiet water. Probably each layer marks the annual deposit; or the result of a freshet.

I ought to observe, that in respect to the clay beds in such basins as those at Deerfield and Westfield, I have obtained no direct evidence that they are underlaid by coarse diluvium. But I can perceive no difference between the characters of the clay found interposed between masses of diluvial gravel, and that from these basins; and the general resemblance of the surrounding region, leads me to infer that these clay beds also are diluvial; and indeed, to consider as such, all that I have found in the State, except the plastic clay of Martha's Vineyard.

Fig. 69.




*Section on the Rail Road: W. Springfield.*

In Duxbury, a mile or two west of the village; in Kingston a mile northeast of the village; and in Plymouth, towards Kingston, as well as near Manomet Hill, in the south part, we find beds of clay, usually of a white color, resembling the plastic clay of Martha's Vineyard, (Nos. 142, 220*b*.) But its layers are horizontal; and gravel is found beneath it. In Duxbury I was told its average thickness is only 13 feet. In Kingston I saw an excavation 8 feet deep, which did not reach the bottom. In Plymouth, north of the village, it is nearly 20 feet thick; and reposes on gravel. When the clay here is penetrated, the water from the subjacent gravel, rushes up with a good deal of violence. I do not regard these facts as conclusive proof that this clay is diluvial: for layers of gravel are interstratified with the clay, sand, and lignite, of the plastic clay formation at Gay Head, and although this latter formation is highly inclined at that place, yet in Europe it is tilted up almost perpendicularly at once place, while at no great distance it is horizontal. Upon the whole, however, I have been inclined to regard the clay along the coast of South Eastern Massachusetts, as resulting from the denudation of the plastic clay formation, which probably in some places lies beneath, by diluvial agency. But I feel no great confidence in this opinion. So far as I have been able to examine the beds of this clay, (and the sections which I have found are not numerous, or very instructive,) they are wanting in those associations that occur at Gay Head. In Mansfield and Duxbury, indeed, I have found beneath gravel, the green sand stratum, which was there about eight feet thick. But the lignites, so common at Gay Head, the white clay without iron, and the red clay are wanting on the continent: as are also all organic remains, except in the Duxbury green sand. I have hence thought that the clays on the continent might with greater probability be imputed to diluvial action, and the gravel beneath them be regarded as diluvial.

Around Boston and in Essex County, the clay is of a light blue color. It is also often a good deal mixed with gravel. And generally, the clay along the sea coast is not divided into as thin and delicate laminæ, as that in the vicinity of Connecticut river. I hence infer that the latter was deposited in more quiet waters, than the former.

I have already referred to the deposit of sand which overlies the clay beds so extensively in the interior of New England and New York, and have regarded its extent and similarity of characters, as evidence of some common and general cause to produce it. I think it impossible to suppose it to have proceeded from the disintegration of the same kind of rock as the clay; although I am aware, that were the sand reduced to the same degree of fineness as the clay, it would approach nearer in character to the clay. But still, it is in general exceedingly siliceous; too much so to form clay, however finely comminuted. In accordance with this view, I have found that at the junction of the sand and clay, the change from the one to the other is gradual. In ascending for instance, from the clay, we find layers of fine clay occurring at intervals, while the sand is very fine. This is shown in Fig. 70; in which the dark layers *b, b, b,* &c. represent layers of clays separated by numerous layers of fine sand. Still higher in the cliff, the clay disappears, and the sand becomes coarser; until at the top, frequently small pebbles are found, and other evidence of agitation in the waters. I conclude, therefore, that the rock from which this sand was worn off, must have been more siliceous than that which produced the clay; and also that the waters must have been more disturbed.

## *Disturbances in the Diluvial Clay.*

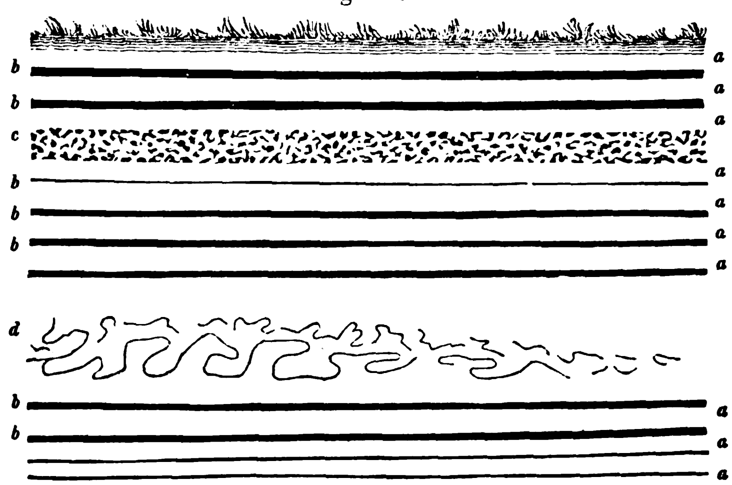
The evidence is quite decided that no general disturbance in a vertical direction has taken place in our diluvial clays. I have, however, noticed a few minor and local disturbances, which are somewhat instructive.

Some years since, I obtained the following rough sketch of a cliff, a few feet in height in Deerfield; the face of which had recently been laid bare by the sliding away of its outer portion. The beds *a, a,* &c. *b, b,* &c. *c,* and *d,* Fig. 70, represent different horizontal layers of sand and clay; the former becoming often very fine, and the latter sometimes approaching to loam. Some of the layers of clay were not more than a half an inch thick; and these in general, with the interstratified sand beds, appeared as if deposited from water perfectly at rest. But the stratum *c,* presented a most remarkable exception. It was composed of angular and rounded pieces of clay, mixed with sand, and obviously resulted from the breaking up of several thin beds of clay and sand, by some unusual agitation of the waters. The stratum *d,* was still more remarkable. It consisted of sand and two layers of clay; the latter being very irregularly bent, as if, when in a plastic state, it had been acted on by opposing lateral forces.

If I mistake not, this section throws light upon the manner in which some of the disturbances in the older rocks may have been produced. Let the stratum *c,* be only consolidated by heat, or otherwise, and we have a perfect conglomerated sandstone, or graywacke.

Let the stratum *d*, be not only consolidated, but partially melted, so as to become in a good degree crystaline; and we have that variety of mica slate or quartz rock, in which the planes of stratification do not correspond with the contorted schistose layers. The undisturbed bed of sand, by the same igneous action might be converted into quartz rock, or mica slate; and the interlaminated layers of clay, into argillaceous slate, or hornblende schist, or both. Thus from this thin tertiary formation, might result hornblende slate, mica slate, quartz rock, argillaceous slate, conglomerated graywacke, and sandstone; and these might present much of the regularity and irregularity peculiar to each rock. And to accomplish this, and also to give the strata an inclined position, we have only to suppose the same volcanic agency to be exerted, which we know has been a thousand times employed in the elevation of the strata, and in the protrusion of the unstratified rocks. Indeed, from some of the sections and descriptions given in the third volume of Lyell's Geology,* of the induration of the Newer Pliocene strata (newer tertiary) in the isle of Cyclops, near mount Etna, it appears that a considerable part of this transformation has there been accomplished.

Fig. 70.

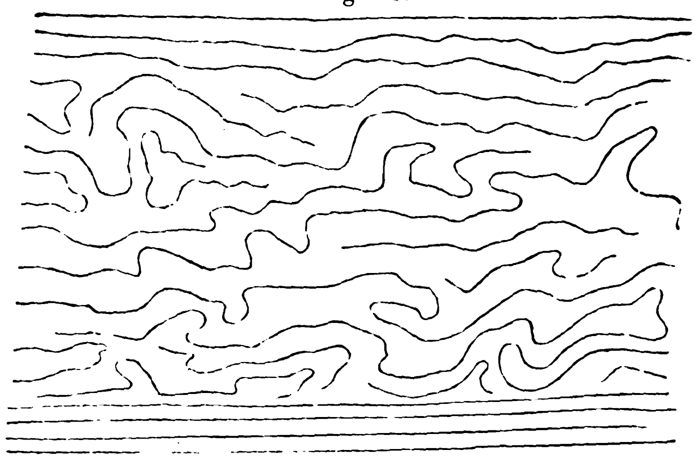



*Section of a Cliff of Tertiary Clay and Sand: Deerfield.*

The preceeding section was obtained on the side of a gully, a few rods west of the stage road at Long Hill, two miles south of Deerfield north village. The last year, I obtained the following sketch from a clay pit, recently opened, a few rods east of the academy, in Deerfield. The contorted portion of the wall of the pit, was about three feet in perpendicular thickness; and above and below, (as shown on the sketch, Fig. 71,) the layers of clay were perfectly regular and horizontal. This proves beyond all question, that the disturbance must have taken place during the period of the deposition of the clay; and that the cause must have been a transient one. A few rods farther to the east, as we pass up a hill, a similar disturbance of the layers of clay appears at a higher level, and of several rods in length; proving that the cause, whatever it might be, recurred at intervals. This case differs from the one first described, in there being no such interstratified layers of sand, as are shown in the preceeding sketch.

* Page 80, first edition.

Fig. 71.



*Contortions in the Clay Beds: Deerfield.*

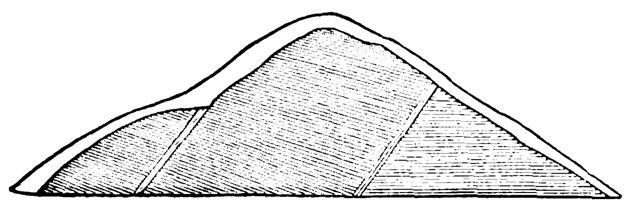
It is a curious subject of inquiry, how the contortions and even folding of the layers of clay, of which the two last figures will give some general idea, could have been produced; especially as the layers above and below the disturbance, indicate the most perfect quietude in the waters when they were deposited. I can conceive no other cause but lateral pressure, after the layers of clay were formed, while the weight of water above, prevented them from being forced out of their place. The great difficulty, however, is to conceive what the force was, which thus acted only occasionally; once perhaps in fifty years. Could it have been masses of ice; which, pressing against the bottom in the vicinity of the disturbance, produced a lateral movement? If we might assume that the bottom was considerably inclined, the mere force of gravity would accomplish the work: but this we have no grounds for doing. Nor is the phenomena explicable, as in the case of sand and gravel, by calling in the agency of tides and currents, as a little reflection will render manifest. In short, the origin of the requisite lateral force is involved in much obscurity.

Fig. 72, represents a peculiar disturbance in the clay, one mile south of the village of Springfield, on the road to Longmeadow. The section runs nearly east and west; is 10 rods long and 30 feet high; showing the north end of a large clay pit, not far from the east shore of Connecticut river. On the right hand side of the section, it will be seen that the layers are horizontal; and these have probably never been disturbed; as this is the common position of the clay in the vicinity. But on the other part of the section, are two seams or faults, passing obliquely across the layers: and the layers are tilted up so as to dip easterly about 15°. Where the fissures occur, there are one or two thin layers of clay between the edges of the laminae;

and I am disposed to consider them as resulting from the sliding of one portion of the clay upon another; whereby the projecting edges of the layers would be broken off, and in consequence of the plasticity of the clay, they might be brought into the form of continuous laminae. At least, I know not what more plausible explanation of the fact to offer.

This is the most considerable disturbance that I have met in the diluvial clay of Massachusetts: nor am I sure that I can give a satisfactory account of its origin. I suppose it produced, however, in some way or other, by the undermining action of Connecticut river. This would cause the clay in a wet season to slide down; as we witness in a multitude of instances every year on a smaller scale. It is true, I should have predicted that if a mass of clay was broken off from the main body and slid down a bank, its dip would be towards the river, and not from it; as is the case at the spot under consideration. Yet I can conceive it possible, if the descending mass met with an obstruction, that the layers should assume the position shown in the section.

Fig. 72.



### *Thickness of the Diluvial Deposit.*

A formation deposited like diluvium must be supposed to have almost every variety of thickness: and such is the case with this deposit. We find it in every place where such materials as compose it could find a lodgment, when acted upon by waters in violent agitation. We should not expect it upon the tops of narrow ridges and insulated peaks, nor upon steep escarpments, except in small quantity, even though carried there by the currents. But wherever narrow valleys or gorges existed, through which the diluvial waters might have rushed, we should expect the detritus to be accumulated in the greatest abundance: and there in fact we usually find it of the greatest thickness, and its characters most strikingly developed. Yet its maximum thickness, in such places, is extremely difficult to be ascertained: especially in a country like ours, where, until recently, no deep excavations have been made. Our rail road cuts furnish, however, some means of judging of the thickness of this deposit. In many places the rock in place has

been reached before the gravel had been penetrated more than 10 or 20 feet. But in others, as in the south part of Palmer, the excavation is 70 or 80 feet deep, and the solid rock has not been reached. But it is in the counties of Plymouth and Barnstable, that the diluvium probably attains its greatest thickness. It is there frequently piled up into hills, (to be more particularly described hereafter,) whose height above the intervening hollows, can hardly be less than 300 feet. The hills around Plymouth, especially to the south, as that called Manomet, must some of them be 300 feet high; and although it is possible that a ridge of rock in place forms their basis, I have not found any evidence of it: and Manomet Hill, at its northern extremity, is worn away by the sea, so as to form a cliff of considerable height: but diluvial detritus only is visible. The diluvial hills in Truro, near the end of Cape Cod, are from 200 to 300 feet high; and as they are composed almost entirely of sand, there is no probability that they are underlaid by solid rock except at the depth at least of the ocean level. So that I think I may safely say, that the maximum thickness of the diluvial covering in Plymouth and Barnstable counties, is certainly 300 feet. For the other parts of the State, I should think it a moderate estimate, to put the maximum thickness at 100 feet. How thick a coat it would form, if spread uniformly over the surface, I can do little more than conjecture. But were I to state my impressions, I should put it at 20 or 25 feet.

The preceding statements are limited to the sand and gravel that are usually considered as diluvium. As to the thickness of the regular layers of sand and clay, I have already made a few statements. In the valley of the Connecticut, I think the sand is usually not more than 15 or 20 feet thick; and Mr. Smith in his account of that valley, already referred to, thinks that the clay beds are no where more than 50 feet higher than the surface of the river, and that their total thickness is usually less than this. But on the margin of the basin in which the village of Deerfield is situated, the clay is exposed not less than 60 feet in depth; nor is the bottom visible any where in that valley. Near the Academy, in that place, it has been penetrated by a well 25 feet, without reaching the bottom; while in the hill a few rods distant, its layers show themselves to the height of 30 or 40 feet; so that here the clay must be 60 or 70 feet thick. I may also state, that in the lowest, or north part of Deerfield meadows, I have seen layers of clay at the bottom of the river, and that spot must be nearly as deep in the earth as the bottom of Connecticut river on the same parallel. The clay and sand therefore, in this valley, must be nearly 100 feet thick. But I do not think we are authorized to suppose that beneath these there can be 100 feet of gravel.

The statements thus far made, I consider as little more than the preliminaries of this subject. The four following points, which I regard as constitut-

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ing its essence, will now receive attention. 1. *Diluvial Elevations and Depressions.* 2. *Origin and Distribution of Diluvial Gravel.* 3. *Bowlders, or Erratic Blocks.* 4. *Diluvial Denudation,* as shown in smoothing the surface of rocks, and in producing scratches, furrows, and valleys.

### 1. *Diluvial Elevations and Depressions.*

The form assumed by the surface of diluvial gravel in many places in New England, is quite peculiar; and constitutes often a most striking feature in the landscape. It is piled up into steep and rounded hills, of almost every form, while the depressions between them exhibit equally anomalous forms. They differ usually from common valleys in this, that they have no outlet; but are more or less scooped out, so as to preclude the idea that they could have been formed by the common eroding agency of water. For the only tendency of that agency at present is, to fill them up, by wearing down their sides; that is, the sand and gravel that surround them. These depressions are usually not more than from 10 to 30 feet deep: I mean, below the lowest part of the elevations that surround them;—not from the top of those elevations. But sometimes the depressions are from 50 to 100 feet deep, in the southeast part of the state. Perhaps the following sketches will assist in giving a more accurate idea of these elevations and depressions than I can do in words. Fig. 73, was taken in the east part of Amherst; where the elevations are not more than from 10 to 25 feet high: but they are very well marked. The spot is on the road from Amherst east village to Belchertown, near the two small ponds, occupying diluvial depressions, between which the road passes.

Fig. 73.

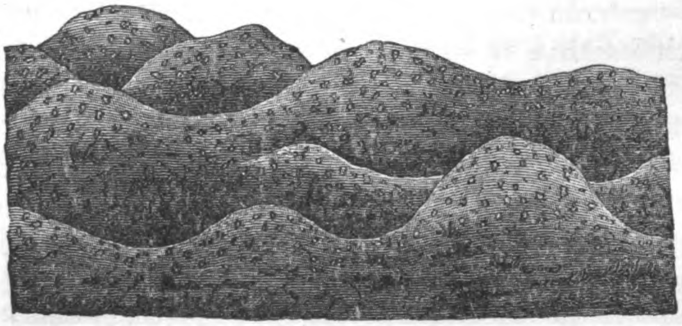
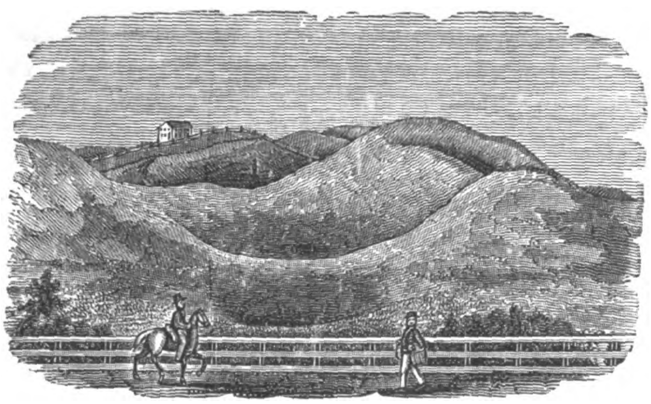


Fig. 74, was taken near the center of Truro on Cape Cod. Here the elevations are sometimes more than 100 feet high, and are made up of coarse sand. Although a meeting house is shown upon this sketch, yet what can be

more dreary than such a landscape! where not a tree appears to relieve the eye, and scarcely a dwelling: for the inhabitants have wisely chosen to build in the valleys, where they are sheltered from the winds. Such a landscape, however, possesses a great deal of scientific interest. It is worth a journey the whole length of the Cape to see such remarkable effects of diluvial action.

Fig. 74.



*Diluvial Elevations and Depressions: Truro.*

The most remarkable exhibitions of these elevations and depressions, as already stated, occur in Plymouth and Barnstable Counties. On the road from Kingston to Barnstable, they are particularly numerous and striking. A better place can hardly be selected to view them, than the ancient burying ground in Plymouth; which itself occupies one of these eminences. And from its top others may be seen on every side, except oceanward, rising in the distance like the waves in a stormy sea. Towards the south, they actually assume a mountain size; and one can hardly persuade himself that he is looking only upon hills of gravel. Beyond Barnstable, we meet with no very striking examples until we arrive at Wellfleet Harbor. From that place to the Light House in the north part of Truro, the face of the country resembles a good deal the surface of the agitated ocean, or rather what is called a *chopped sea;* where the waves interfere with one another. The sand is piled up sometimes to the height of 200 feet, with corresponding cavities; the sides of which are often quite steep. Near Truro Harbor, where the sketch Fig. 74, was taken, the most striking examples occur.

I might mention numerous places in the interior of the State, where these diluvial hills and valleys exist. But I shall name only a few of the most striking. In the eastern and southern parts of Franklin they are common and well characterized: but not very elevated, or deep. They are very frequent also in the north part of Middlesex county, and northeast part of Worcester

county. Perhaps the town of Groton contains as good examples as any place; especially about two miles east of the village. In that region the elevations rarely exceed 20 feet: and here they are situated on extensive plains, and not in the vicinity of high mountains; as is frequently the case. The cemetery at Mount Auburn, in Cambridge, affords a tolerable example. Nearly all the inequalities of ground there, which give such a romantic aspect to the place, are the result of diluvial action. On the road from Spencer to Brookfield, we witness some, though not striking specimens. Along the eastern margin of the valley of the Connecticut, are many good examples. One has been already referred to in Amherst. Another may be seen in the east part of Granby, where the depressions are 30 or 40 feet deep. In passing from Montague to Miller's river, are some good examples. Some very striking ones also may be seen in passing from the center of Bernardstown towards Northfield, only a mile or two east of the former place. I ought likewise to have referred to an example on the road from the center of Greenwich to Greenwich Village, in the north part of the town. These are chiefly cavities scooped out of the sandy plain, as if by the hand of a Titan. The same is true of those in Montague.

Near the foot of the western slope of Hoosac Mountain, or on the eastern margin of the principal valley of Berkshire, these elevations and depressions are quite common. In passing up the Hoosac range from Dalton and Lee for instance, we see them very strikingly exhibited. In North Adams they consist chiefly of insulated conical hills, so regular as easily to be mistaken for artificial mounds. South of the village of North Adams about 12 of these hills, some of them not less than 100 feet high, are ranged nearly in a line two miles in length: and they give a singular aspect to the landscape. An attempt has been already made to exhibit them on Fig. 15. Northwest of the same village, are others still more picturesque; as shown in Plate 3. At the eastern foot of Monument Mountain in Great Barrington, is another example of similar insulated cones, which are exhibited on Fig. 19. Near the same spot a little distance from the mountain, may be seen numerous examples of diluvial cavities as well as depressions.

Sometimes a single conical elevation, such as those described above, is seen rising from a plain of considerable extent, and having an appearance extremely artificial. I noticed one of remarkable regularity in the northeast part of Lee, on the road to Washington. Excepting a slight irregularity on one side, this is a perfect cone, 30 or 40 feet high. Another of these hills may be seen in the east part of Pittsfield, on the north side of the stage road to Dalton. Another exists about three miles west of Northampton, on the south side of the road to Williamsburg. Another may be seen in Enfield, by the side of a small stream, about two miles beyond the village on the road to Greenwich. In several instances I have seen such hills crowned by a *liberty pole*, to constitute the center of attraction for a fourth of July.

Whatever theory we may adopt as to the origin of diluvial hills and cavities in general, we must probably call in the aid of alluvial agencies to account for these singular insulated conical eminences. Probably they are the remnants of a once extensive diluvial deposit, which has been gradually carried away by existing streams. Some of them, however, are so situated, it seems to me, as for instance those at the base of Monument Mountain, that no existing stream could have accomplished the work: and I am not sure but in nearly every case, they may have resulted from diluvial agency; though I confess I am not prepared to explain the *modus operandi.*

Conical elevations of this description have in many countries arrested the attention, and generally have been regarded as the work of man. Prof. Struder mentions a case of this sort in the vicinity of Berne, in Switzerland, and he says, that "in the late demolition of the fortifications, these

eminences, which were universally supposed to be the work of art, thrown up on the common level of the ground, were penetrated to their center, and it was found that they consisted for the most part, of enormous heaps of Alpine blocks, whose interstices were entirely filled up with smaller gravel and sand, &c. This chain of hills is manifestly the last remains of a much more general overspreading of detritus, which has been torn to pieces and carried away by later water courses." *(Amer. Journal of Science, Vol.* 36. *p.* 326.) Who can doubt that the greater part of those mounds in the Western States, which have been supposed to be the work of man, are in fact the work of water? An able writer says of them, that he "had never examined one that was not composed of different layers of earth, invariably lying horizontally to the very edge of the mound." *(Illinois Magazine, Vol.* 1. *p.* 252.) Such an arrangement of materials is entirely beyond the art of man, and can be accomplished only by water. Besides, so large and numerous are these mounds at the West, that their construction would have required all the millions of our globe for ages. I would not deny that the early inhabitants of this continent often selected these mounds for places of habitation, fortification, and burial; nor that they have left some small mounds erected entirely by themselves. But I cannot doubt that the greater part of those elevations, which are pointed out as the work of man, are in fact the work of water. And though I shall doubtless be censured for this opinion, I hazard the prediction, that a few years more will witness its general adoption. I have great confidence that the able geologists who are so successfully exploring the Western States, will shortly set this matter right; that is, they will show that the greater part of these mounds have resulted from diluvial or fluviatile action, or from both combined.

But to return from this digression: what origin shall we assign to the remarkable elevations and depressions in the diluvial gravel of Massachusetts? I do not mean what is the origin of the diluvial currents: But admitting their existence, which no one will deny, how could they have produced these hillocks and cavities? That they were the result of running water, no one who has seen them, can doubt. He will see that no other agent could have given them their present form: and moreover he will see that they bear some resemblance to the appearance of sand and gravel, which have been exposed to violent and eddying currents in the beds of existing streams. But they occur on a scale so immensely larger than any thing now witnessed, that the mind is led to inquire whether they could have resulted simply from running water. In the beds of our swiftest currents, we see somewhat analogous cavities and elevations, a few inches only in depth and height; or possibly a foot or two: but what current could have formed them 50, or 100, or 200, feet high? Especially, what stream could scoop out of a nearly level plain, holes 15 or 20 feet deep, over an area of a few rods only, while the adjoining soil remains undisturbed? Now just such examples occur not unfrequently, as on the sandy plain between Greenwich center and Greenwich village; and in the north part of Montague. They appear almost as if a former artificial excavation had been made there; whose sides have fallen in. Now I confess I can hardly believe that all these cases are due solely to running water, unless it was poured over the surface with a power and a violence vastly exceeding anything now witnessed. There is another agency

which I have often suspected may have been concerned: and that is ice. Let us suppose that large blocks of ice were arrested by some narrow gorge, and as the diluvial waters subsided, they settled down upon the diluvium that had accumulated. The current would now be compelled to follow many a devious course among the irregular blocks. Its velocity also, would in some places be much increased; and a natural effect would be, that it would wear away the gravel and sand around some of the blocks of ice. They would be gradually undermined and settle down; and perhaps cavities as deep as we now witness, might be scooped out. There are to be sure, difficulties in such an hypothesis. But to my mind it does afford some relief to the difficulties of this case, especially as I have seen similar excavations in Deerfield meadows, made by the water running among blocks of ice, which in the spring had been deposited there by a flood from the adjoining river. Some of these are 4 or 5 feet deep.

I have not met with any description of phenomena in the diluvium of Europe analogous to our diluvial elevations and depressions, except those insulated hillocks just referred to near Berne, and perhaps the Ose and Sandosar of Sweden, which however are quite different. But I can hardly believe that they do not exist in Europe: for nearly all the rest of our diluvial phenomena correspond to those of Europe.

One statement I ought perhaps to add in respect to these elevations and depressions. I have never seen them fully developed except where the diluvium was either sand or gravel. If large bowlders are present, although the surface may be uneven, it has not the peculiar contour exhibited where these do not exist.

There is another fact also that may be of some consequence. The depressions are not unfrequently occupied by ponds. Hence the great number of ponds in Plymouth, Falmouth, &c. In some instances I have seen ponds in two depressions only a few rods apart which had a permanent difference of level of several feet. This is the case in the ponds already referred to in the east part of Amherst between which the road passes. Resulting probably from similar causes is a fact of at least some local interest, which I apprehend is not generally known. At the east end of the Holyoke range, and separating it from the gneiss range, are three ponds connected by a brook, and a brook also runs out both at the north and south end of the extreme ponds, both of which brooks empty into Connecticut river, one running north and the other south of the Holyoke range; so that *in fact that mountain is an island.*

### 2. *Origin and Distribution of Diluvial Sand and Gravel.*

Although sand and gravel constitute the greatest part of diluvium, yet they do not present as many instructive phenomena as bowlders: and I shall do little more at this time, than to describe those situations where they are most and least abundant. It may be stated, as a general fact, however, that

this sand and gravel have been drifted in a southerly direction; or rather, for the most part, a few degrees east of south. If we begin with the extremity of Cape Cod, we shall find that probably the sand of Provincetown is alluvial: that is, washed up by the ocean. But when we come to High Head, in the north part of Truro, we know that the sand which constitutes the entire soil is diluvial; from its occurrence in those peculiar elevations already described. In this sand, through the towns of Truro, Wellfleet, Eastham, Orleans, Harwick and Chatham, it is rare to meet with bowlders, or even gravel. When they do occur, as gravel does near the Light House in Truro, they consist of the peculiar argillaceous slate, constituting the outer islands in Boston Harbor, with porphyry, and graywacke conglomerate—all of which rocks occur in and around Boston Harbor; and probably extend outwards beneath the ocean far into Massachusetts Bay. As we pass westerly, we find in Brewster and Dennis, large blocks of stone mixed with the sand, but very little gravel; and this is the case even till we reach the borders of Plymouth. Here the sand and gravel form an extensive deposit, piled up, as I have elsewhere described, into hills several hundred feet high. A large proportion of the gravel, as well as the bowlders, consists of a granitic gneiss, which many would probably denominate granite; and which exists in place in Rochester, New Bedford, and probably also beneath the diluvium on Cape Cod. The most perfectly worn pebbles and bowlders, however, are those of the granite, sienite, porphyry, graywacke, and flinty slate, which abound around Massachusetts Bay, from Plymouth to Cape Ann. The greater part of Plymouth and Bristol Counties is covered with diluvial sand and gravel: which is a mixture of all the rocks (ex. gr. granite, sienite, compact feldspar, porphyry, greenstone, conglomerate, and gneiss,) which exist in place in a northerly direction, even as far as 30 or 40 miles. The towns of Scituate, Cohassett, and Hingham, however, are in a good measure swept of gravel and sand; and not a little of the surface presents ledges of water worn rocks.

The character of the diluvium in Duke's County is very similar to that of the south part of Plymouth and Barnstable Counties: viz. coarse sand with large bowlders. Gravel is not abundant; but when found it is composed of worn fragments of gneiss, granite, porphyry, &c. such as exist in place around Massachusetts Bay. Nantucket is mostly covered with sand, having the same origin. So completely are Martha's Vineyard and Nantucket covered with diluvium, that the subjacent tertiary strata are rarely visible, except in sections along the coast.

As we proceed westward from the coast, we find diluvial gravel, the most abundant probably near the junction of the stratified and unstratified rocks; which is also, for the most part, the line where the county begins to rise above the general level of the graywacke deposits. This rise, however, is not sudden; and all the elevated region embraced by the gneiss formation of Worcester County is covered by diluvium. But along the line above mentioned, the pebbles are accumulated in the greatest abundance; are more perfectly rounded; and the marks of violent action in the water are more manifest. And this is the case generally in the state, on the margin

of valleys: that is, we there find the diluvial gravel more strikingly exhibited than in the central parts of the valleys; or upon the tops of hills. It may be, however, that this is only because the bottoms of the valleys are more covered than their margins, with alluvial deposits; so that the diluvium is more concealed: Or because alluvial agencies have carried away the diluvium more in the central parts of the valleys than along their borders. It might be thought, that it would explain the fact under consideration, to suppose that the margin of these valleys once constituted the shores of the ocean; and that the gravel was washed up by the breakers, while the land was gradually raised. But in this case the deposits would not show those striking elevations and depressions already described; since nothing of the kind now occurs upon the coast. And besides, in this case the detritus would not have been drifted in a southerly direction, without much reference to the course of the valleys, as we find it to have been. From all these statements we may infer that we ought to expect diluvium to be most abundant near the base of the hills that bound our valleys, especially north and south valleys; and such is their almost universal direction in Massachusetts: I mean the larger ones.

In the broad part of the valley extending from Merrimack river through Worcester, it can hardly be said that there is any special accumulation of gravel upon the margin: For we find it widely spread over the bottom of the valley; as in the region around Groton. No part of this valley, however, is deep; and the alluvial deposits are very limited; and therefore, conceal but little of diluvium.

In the valleys of Berkshire and of Connecticut river, the diluvial gravel is far more abundant on their eastern than their western margin. This is explained by the fact that the diluvial currents in that part of the State had a direction considerably east of South.

No considerable portion of the State is so destitute of diluvial gravel as Essex County. This is especially the case as we approach Cape Ann, its eastern extremity. Although the bowlders there, and in most other parts of the County, are quite numerous, the gravel has been mostly swept away, leaving naked rock over a considerable part of the surface.

The tops of our high and precipitous mountains are generally wanting in diluvial gravel. But we meet with it in small quantities even upon the summit of the most naked and precipitous of these. Thus we learn that it is generally wanting on the mountains, not because diluvial agency has not operated there, but because gravity has brought it down to a lower level.

In short, while we see every where decided evidence of diluvial action in the southeasterly direction in which our diluvial sand and gravel have been drifted, it is clear that the valleys which existed at the diluvial epoch, somewhat modified that action; and caused the detritus to accumulate in particular places. And these accumulations are usually just in the situations where we should expect them, if a very strong current had swept southeasterly over the surface as it now exists: but by no means in such situations as they would be brought, by the waves of the ocean, acting upon the shores, as the land was gradually lifted from the waters.

### 3. *Bowlders or Erratic Blocks.*

It is chiefly because their greater size renders them more conspicuous, that the phenomena of bowlders are more striking than those of sand and gravel.

For the origin and dispersion of both are essentially the same. Nevertheless, bowlders are by far the most instructive index of diluvial agency in Massachusetts.

## *Form and Size of Bowlders.*

Bowlders are usually more or less rounded; often perfectly so; especially those of the smaller size. These are often as perfectly smoothed as attrition will make them. Sometimes, however, only one side is smoothed; and this is frequently crossed by furrows, or scratches; as if the bowlder had been driven over the solid ledges while firmly fixed in a mass of ice. But these scratches might have been produced in another way. Such furrows are very common in New England upon the rocks in place; and if such a surface had been broken up by diluvial or alluvial agency, as we frequently see is done in the beds of mountain torrents, the smoothed and furrowed surface might constitute one face of the blocks thus formed; so that we cannot be sure this effect was produced in the manner above suggested by means of icebergs. Yet such may have been their most common origin.

The largest bowlders are usually less rounded by attrition than the small ones: but not unfrequently their angles have disappeared by exfoliation. The hardest rocks, however, such as quartz, porphyry, and many granites, are rarely acted upon in this manner. I ought to remark here, that where a ledge has been merely broken into fragments, which have never been removed from their original bed, I do not regard them as bowlders; even though somewhat rounded by exfoliation. I do not, for instance consider such masses to be bowlders as occur in the vicinity of the Purgatory in Sutton, and in Great Barrington, nor those which lie at the base of the trap ranges near Connecticut river, nor those of Monument Mountain.

Unless a block of stone exceed six inches in diameter, I have not been in the habit of regarding it as a bowlder. From that size up to 30 or 40 feet in diameter, they occur in Massachusetts. I shall name only a few of the largest which I have measured.

On the east bank of Taunton river, a few rods south of the mouth of Fall river, (and of course just within the limits of Rhode Island,) is one of the largest bowlders that I have seen, of coarse graywacke conglomerate. It has been uncovered by the removal of diluvial gravel; and much of the bowlder also has been blasted away. But I think it could not have been less than 40 feet in diameter. Supposing it a cube it would weigh about 5400 tons! I shall have occasion to refer to this block again, as exhibiting another curious fact.

A bowlder of fine grained sienite is poised upon the same kind of rock, in the southeast part of Bradford; whose form is nearly cubical, and the length of one of the sides 30 feet. Its weight is of course about 2310 tons.

In the village of Norton, in Dr. Bates garden, lie two bowlders of common graywacke, about 20 feet in diameter; which, supposing them cubes, must each weigh about 675 tons.

In the north part of Troy, near the stage road, I measured a bowlder of graywacke, whose horizontal circumference is 110 feet. Probably if measured perpendicularly to the horizon, its girth would be somewhat less. Supposing the mean circumference to be 100 feet, its diameter would be 32 feet; and if a sphere, its weight would be 1447 tons.

On the beach at the foot of Manomet Hill, in Plymouth, there lies a parallelopiped of porphyry, whose horizontal circumference is 60 feet.

On the beach at Gay Head, on Martha's Vineyard, are three very large bowlders of granite; one of which measures 90 feet in circumference.—Consequently its diameter is 29 feet; and if a sphere, its weight would be 1060 tons.

Poised upon the conical eminence of nearly naked granite, just south of the village of Fitchburg, called Rollstone Hill, lies a block of an entirely different sort of granite, about 45 feet in circumference, measured horizontally. Supposing it a cube its weight would be 112 tons. This block is porphyritic: which is not the case with the rock in place on which it rests.

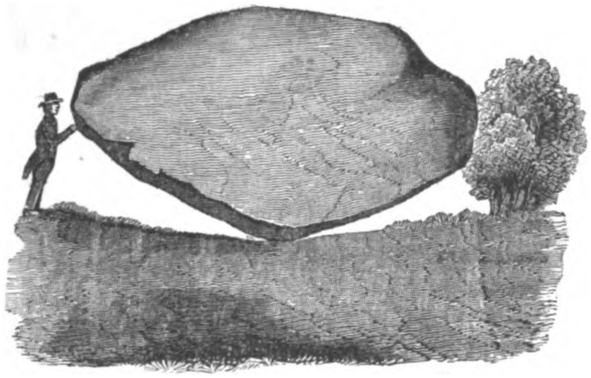
On the west side of Hoosac Mountain, which is very steep, in the northeast part of Adams, and 1500 feet above Adams village, is a bowlder of the Clarksburgh granite, nearly 20 feet in diameter, which must have been carried across the valley below. I have not seen this; but state the fact on good authority.

It seems difficult to conceive how running water should have been able to remove such enormous masses. Yet it is certain that all of them have been transported quite a distance. Those in Fall River and Troy for instance, must have been brought from the opposite side of Taunton river, or from several miles north. That in Plymouth corresponds to ledges in the Blue Hills, near Boston: but I know of no porphyry ledge south of those Hills: and they are 30 miles north of Manomet Hill. Is it possible that such a bowlder could have been carried so far? The bowlder in Fitchburg, that has been discribed, must be have been brought several miles and across deep valleys. The same is true of that in Adams; and the valley which it must have crossed, is a very deep one. In contemplating this Sisyphean labor, however, we ought to recollect that a rock in water loses nearly half its weight.

### *Rocking Stones.*

When large bowlders are so poised upon rocks in place that a moderate force will sensibly move them, they are called rocking stones. They are common in Massachusetts. Fig. 75, is an interesting example that may be seen 1 1-2 miles east of the village of Fall River.

Fig. 75.

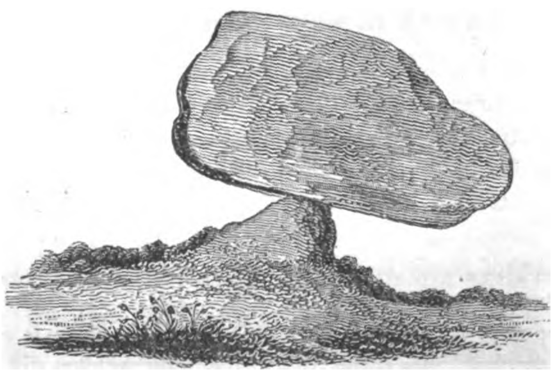


*Rocking Stone: Fall River.*

The rock in place in Fall River is granite: but this rocking stone is coarse conglomerate, which has been brought to this spot by diluvial action. And the contrast in the characters of the two rocks increases the interest with which we regard the rocking stone: because the most careless observer perceives that it is a stranger, brought thither by some powerful agency of nature. Its horizontal circumference is 58 feet, and its medium perpendicular thickness, 8 feet. By an approximate estimate, I find its weight to be 140 tons. Yet with one hand it may be sensibly moved; and by using both hands, it can be rocked so as to oscillate at the top 2 or 3 inches. It lies upon the very brink of a quarry; so that I fear it may ere long be precipitated from its present interesting position. It lies close to the old road from Fall River to New Bedford, and was pointed out to me by Rev. Mr. Fowler of the former place.

Fig. 76 is a sketch of a bowlder of granite, 17 feet long and 27 feet in circumference, resting upon granite or gneiss: apparently just ready to fall, and yet five men with levers were unable to throw it from its base. It is in Berlin, one mile east of the meeting house, on the road to Bolton. I am indebted for the sketch and description to Dr. Lyman B. Larkin of Wrentham. He has also described another bowlder in Berlin, near the house of John Larkin, which weighs 160 tons; and yet can be moved by a boy six years old. Indeed, he thinks a strong wind would put it in motion. It is composed of porphyritic granite, resting upon gneiss.

Fig. 76.



*Rocking Stone: Berlin.*

Fig. 77 represents a mass of porphyry, 10 or 12 feet in diameter, lying on a ledge of the same kind of rock in the north part of Chelsea, near the toll gate, on the Newburyport turnpike,

but I do not know that it can be easily moved. Fig. 78, is a view of a divided block of gneiss, which is nearly 10 feet high, and is so accurately poised upon a ledge of gneiss, that at a little distance it seems as if it could easily be thrown over; but this is no easy matter. It occurs in the west part of Barre, on the road to Dana.

Fig. 77.

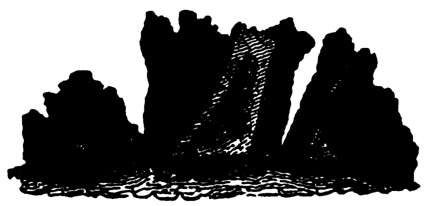
*Rocking Stone in Chelsea.*

Fig. 78.

*Double Rocking Stone in Barre.*

In Brewster, on Cape Cod, is an enormous mass of granitic gneiss 16 feet high, and 160 in circumference: of which a drawing is annexed in Fig. 79. This is split into 6 or 7 pieces, and appears as if it had been subjected to a powerful action of water, or some other agent, in former times. Probably it is the remains of a ledge which diluvial currents have worn away or buried. The sketch was taken from the west.

Fig. 79.



*A Rent Rock in Brewster, Cape Cod.*

I have noticed a rocking stone near the center of Greenwich, weighing 30 or 40 tons, which might be moved by a lever. One may be seen in Chilmark, on Martha's Vineyard. In the 7th. Vol. of the Am. Journal of Science, is a drawing and description of one, of more than 46 tons weight, in Roxbury; which "a child of six years old can easily move with one hand." Mention is there also made of one on the Salem Turnpike; of three in the vicinity of Providence, and one in Framingham. Gen. E. Hoyt, also, describes one in the bed of Deerfield river, in Zoar.

Dr. B. Haskell formerly of Sandy Bay on Cape Ann, has furnished me with the following description of a rocking stone in that vicinity.

"We have a rocking stone within two miles of Sandy Bay, which is equal to any in interest, that I have ever seen described. Its shape, though tolerably regular, will not easily admit of its measurement. Yet, Ihave no hesitation in saying that it will weigh more than 45 tons. It can be moved by the effort of one hand, and its motion is perceptible at some distance. Formerly it attracted attention. You will find it described in Mather's Magnalia."

*Number and Situation of Bowlders.*

With the exception of the sandy extremity of Cape Cod, Nantucket, the east part of Martha's Vineyard, and certain sandy plains which were deposited either by the retiring diluvial waters, or by alluvial agencies: such as Seekonk Plain, and the sandy part of the valley of the Connecticut river, bowlders occur every where. Those are most conspicuous which are perched upon the tops of the hills; and landscapes thus studded, are not unfrequent. With one or two exceptions, they are more striking in Falmouth and Sandwich, and on Martha's Vineyard, than any where else. So large and numerous are they here, that again and again have I felt confident there must be ledges upon the hills, until I had gone to the spot, when I never failed to discover that nothing but bowlders, often of great size and crowded together, were all that could be found, partially enveloped in sand. Any one who doubts the tremendous power of diluvial currents, should pass from Plymouth to Falmouth, from Sandwich to Wareham, and along the whole western side of Martha's Vineyard; and I am sure he would be amazed to see what water has done. I can hardly believe that such large and so numerous bowlders as are there driven pell-mell together, could have been transported a great distance. Yet it must have been a most powerful agency that could tear them from their beds and pile them up into hills some hundreds of feet high.

Probably, however, the most remarkable exhibition of bowlders in the state, is in the west part of Cape Ann. Here they are rendered more conspicuous by the absence of sand in a good measure; and the want of trees. In approaching that part of Gloucester called Squam, from the south, the bowlders literally cover the surface, over an extent of many square miles; and nothing can appear more desolate. As I once came in sight of this landscape, I was amused by the exclamation of my assistant,* who said,—"just so must the world have appeared to Noah, as he came out of the ark." An attempt has been made to depict this landscape in Fig. 28, on page 270.

There is scarcely a mountain in the state, however precipitous and narrow at the summit, where erratic blocks may not be found; though as we might expect, the higher and narrower the summit, the fewer their number. Some cases of this sort I shall mention farther on. But it is in valleys, and especially on the northerly slopes of hills, that these blocks are most numerous. The southern part of the valley of Blackstone river, especially in Uxbridge, presents vast numbers of bowlders, and many of great size. They are abundant in the southeastern part of Westminster, in what is called *Notown*. At the northern foot of Mount Tom, which is composed of sandstone and trap, bowlders of sienite and common granite are accumulated in great numbers; and I might name several places in Berkshire County, as in the northeast part of Great Barrington, and on the Valley Road from Dalton to Lanesborough, where immense numbers of quartz bowlders are brought together; but it is unnecessary to be more particular. For one can

* Rev. Story Hebard, now Missionary in Syria.

hardly travel through the state, without meeting with many remarkable displays of these wrecks of mountains.

It has been frequently asserted in respect to bowlders in other countries, that they are imposed upon the diluvial sand and gravel and not disseminated through them. And a superficial examination of their situation in Massachusetts, might lead to the same conclusion in respect to our bowlders. For they are every where scattered over the surface, as if dropped upon the sand and gravel, and not promiscuously mixed with them. But by an examination of diluvial cliffs, that are crumbling down, and excavations for roads, rail roads, and canals, through diluvium, it will be obvious that the large bowlders are not confined to any one part of the deposit: and that with occasional exceptions, they are more numerous and obvious on the surface, because the diluvium in which they were once enveloped, has been worn away. The largest bowlder described above —that near Fall River village—was originally covered by at least 10 feet of gravel. At the rail road cut in the south part of Palmer, of which a section is sketched on Fig. 65, the large bowlders are scattered promiscuously through the gravel, both above and below the included clay beds. A few miles farther east, on the same rail road, in Warren, still larger blocks may be seen deeply imbedded in the gravel. The same is the case at the cliff at the north end of Manomet Hill in Plymouth; and I might refer to many other places in illustration of the same fact. I do not mean that every part of a diluvial deposit is of the same degree of fineness or coarseness; for the sections which I have given show the contrary. But I mean that the large bowlders are confined to no part of the deposit—certainly not to the surface. Hence we may be sure that the same agency that has accumulated the gravel and sand, has also brought together the bowlders.

I think, however, that there are some exceptions to this statement. I have sometimes, for instance, met with a bowlder of several tons weight, on the surface of an extensive sandy plain: and I can hardly believe in such a case, that it was not brought there in a manner somewhat different from that in which the sand was accumulated. So when a bowlder is poised upon the top of a narrow and precipitous ridge, and it is impossible to believe that it has been driven up the steep escarpment, or even sometimes the nearly perpendicular wall of the mountain, we must suppose, either that it was left there before the elevation of the mountain, or transported thither by an iceberg, or other floating mass.

## *Dispersion of Bowlders.*

The most important fact which I have to state, respecting the dispersion of bowlders from their original beds, is, that they have uniformly been drifted in a southeasterly direction. To this statement I scarcely know of a single exception.

Another important fact is, that the size and number of bowlders gradually diminish as we go southerly from the ledge whence they were detached. To this statement there are more exceptions than to the first.

A third fact of importance is, that the direction of existing mountains and valleys, has exerted but little influence upon the course which bowlders have taken.

Yet in the fourth place, the present hills and valleys appear to have existed at the period of the dispersion of the bowlders.

I shall now refer to particular localities in proof of the positions above laid down.

In order clearly to understand the examples which I shall now present of the dispersion of bowlders, it will be important to examine the Map appended to this report, which gives a general view of our mountains and valleys: along with the strike of the strata, in order to get an idea of their direction: And also the Geological Map, to learn the relative situation of the different rocks.

When I began to examine the State geologically, I traveled east and west; commencing with the line of towns bordering upon Connecticut, and returning through the line of towns next north. Thus essentially did I go over the whole state: And I had not passed through more than two tiers of towns, before I found that uniformly, in order to trace bowlders to the beds from whence they were derived, I must travel either north, or northwesterly, a greater or less distance. This discovery was frequently of great use to me; and for the last ten years, I have acted upon it very often; *and never found it to fail me in scarcely a single instance.* In vain have I examined the country on the north, east, and west sides of a particular rock, for bowlders of it. But they always appear upon the south or southeast side.

If we pass from the most easterly point on Cape Cod, where bowlders occur, say from Orleans, and proceed westerly through Brewster, Dennis, Yarmouth, Barnstable, Sandwich, Wareham, and Rochester, to New Bedford; we shall find the greater part and the largest of the bowlders to be a granitic gneiss, which appears in place in Rochester and New Bedford, and probably exists in ledges a little beneath the surface on the Cape. But mingled with these bowlders, over the whole distance, we shall find others, often 3 or 4 feet in diameter, of graywacke conglomerate, porphyry, compact feldspar, trap, granite, and sienite: and precisely such varieties of those rocks as are found in the region around Boston. The conglomerate, trap, sienite, and granite, are found in place also, from 20 to 30 miles south of Boston:—and the conglomerate in interrupted patches to the extremity of Rhode Island. But the compact feldspar and porphyry, I have not discovered in place south of the Blue Hills in Dedham, Canton, Randolph, and Hingham. In Hingham especially, is a blood red variety of compact feldspar, rarely met with in other places; and fragments of this rock are found with more or less frequency, all the distance to Martha's Vineyard, where I have met with fragments a foot in diameter. This would indicate a direction to the diluvial current a few degrees east of south. If we suppose the other bowlders described above as strewed along the Cape, (and I might add also the Elizabeth Islands, and Martha's Vineyard, whose diluvium is of the same character,) to have proceeded from the vicinity of Boston, it would require the current to have been almost southeast to reach Brewster and Orleans. But by examining the islands in Boston Harbor, along the northerly side of Massachusetts Bay, we shall find them composed of slate, conglomerate, sienite, and porphyry; and hence the probability is strong, that these rocks extend, perhaps a great distance, beneath the ocean; and may have been above the present surface at the diluvial period. So that I conceive the precise direction of the diluvial current is more accurately indicated by the red compact feldspar, than by the other bowlders, which merely show that the course was southeasterly.

At the north end of Manomet Hill, three miles south of Plymouth village, is an almost unexampled accumulation of bowlders; and nearly every variety of granite, sienite, and porphyry, found along the coast, as far as the extremity of Cape Ann, with occasional blocks of conglomerate, may be found there. I have already described an enormous block of porphyry at this spot; and it is not an insulated one. Indeed, so abundant and so large are the porphyry bowlders here,

that I can hardly conceive they could have been brought from the Blue Hills, which are nearly 30 miles distant: and I am disposed to believe, either that this rock exists in place not far north of Plymouth, and has been overlooked by me, or that a ridge of it did once exist there, which has been entirely swept away by diluvial and alluvial agencies.

If we go from New Bedford to Rhode Island, either along the coast, through Westport to Little Compton, or farther north to Tiverton, or even to Fall River, we shall find most of the bowlders to be gneiss and granite; which are the rocks in place. But mixed with these, are frequent examples of graywacke conglomerate; a rock which is very abundant in the graywacke formation, shown on the map several miles north of the routes above specified. Some of these bowlders are 5 or 10 feet in diameter; even those that have been transported 15 or 20 miles. It may perhaps be imagined, that the graywacke formation once extended over the region now marked as gneiss and granite; and that these conglomerate bowlders are its wreck. But this is rendered improbable by the fact, that as we proceed northerly towards the graywacke, they increase in number and in size. And it is interesting to pass from Fall River to Berkley, and witness the great abundance of these bowlders. A geologist, not familiar with our diluvial phenomena, would be very apt to conclude that he was in a region of coarse graywacke: for he would see no other rock for miles. But he would search in vain for that rock in place; and occasionally he would find ledges of granite: and when he had gone as far north as Berkley Neck, he would see from whence the conglomerate bowlders, so thickly strewed along the eastern bank of Taunton river, were derived.

In several places, as may be seen by the Map, the tracts of graywacke are bounded on the north by unstratified rocks; chiefly sienite, granite, and greenstone. And as we approach these unstratified rocks from the south, even when eight or ten miles distant,we begin to find their rounded fragments; until at length, and that often at the distance of two or three miles from the unstratfied ledges, they equal, or exceed in number, those of graywacke; rendering it often exceedingly difficult to ascertain the boundaries of the different formations. But on the other hand, no bowlders of graywacke are found in the primary regions lying north of the graywacke in place, unless deposits of graywacke occur still further north.

The particular towns, where we find the most striking examples of a mixture of bowlders of granite, sienite, and greenstone, with those of graywacke, which is the rock in place, are Attleborough, Mansfield, Norton, Bridgewater, Brighton, Newton, Needham, and Watertown. The Map will show, that a few miles northerly from these towns, are deposits of granite, sienite, and greenstone. On the other hand, in Stoughton, Randolph, Dover, Dedham, Braintree, &c., we find graywacke bowlders, mixed with those of the rocks in place; and these were obviously derived from the graywacke formations lying notherly from these places.

Perhaps the example more definite and decisive than any other on the subject under consideration, occurs in Rhode Island. In Cumberland a large hill exists of magnetic iron ore; a considerable part of which contains distinct crystals of feldspar, so as to become beautifully porphyritic. A rock so peculiar cannot be confounded with any other. Now if we pass along the north, east, and west sides of this bed of ore, even very near it, no scattered fragments of it are seen among the bowlders. But on the south side, they occur all the way to Providence, decreasing in size. Whether they may be found on the west side of Narraganset Bay, south of Providence, I cannot say: but I met with several pieces at the southern extremity of Rhode Island, in Newport, of only a few inches in diameter. These must have traveled nearly 35 miles from their bed, in a direction a few degrees east of south, which corresponds with the facts already stated, especially in regard to the red compact feldspar.

In passing through the southeast part of Worcester County, I repeatedly met with a remarkable variety of porphyritic granite, in which the imbedded crystals of feldspar are unusualy large; so that the rock has been confounded by those little conversant with geology, with conglomerate

(No. 1464). But I did not find this rock in place, until I reached Harvard; where it is abundant. North of that spot I have met with none.

Bowlders are very numerously spread over every part of Worcester county: But as most of the rock there is gneiss, which extends northerly I know not how far into New Hampshire, we do not see generally such striking examples in these bowlders of the dispersion of one sort of rocks over the surface of another, as in the cases already described. Yet in the case of one rock, viz. greenstone trap, the southerly direction of the diluvial current is as striking as in any part of the state. This rock exists, as may be seen by the Geological Map, in numerous beds, or protruding masses, in the gneiss; and from the place where its ledges appear at the surface, which is usually only a few rods in width, its bowlders may be traced southerly with great exactness for several miles: always decreasing in number and size: But in no other direction can they be found. And it is interesting to notice how strait a course they have taken; and how little they diverge on either side. Sometimes, it is true, I have followed one of these trains northerly, without being able to find any of the rock in place: But their numbers and size increase until suddenly they all disappear. Who can doubt, but that in such a case, the ledge has been worn away so much, that it no longer appears above the surface?

In the more elevated parts of the valley of Connecticut river, especially on its eastern margin, the same phenomena respecting the dispersion of bowlders, that have been detailed, are strikingly manifest. It will be seen on the Map, that the numerous formations which here interlock, must give a very mixed character to the bowlders, if they were carried southerly by aqueous agency. Thus, the red sandstone of Bernardston, Gill, and Greenfield, is covered by gravel and bowlders derived from the argillaceous slate, quartz rock, hornblende slate, and granite, found in place a few miles north, either in Massachusetts or Vermont. The same sort of bowlders occurs on the elevated sandstone and trap range in Deerfield, with the addition of those two rocks. In Amherst, the detritus is a mixture of granite, gneiss, quartz rock, hornblende slate, greenstone trap, sandstone, and coarse conglomerate; all of which rocks occur in place a few miles north, in Sunderland, Montague and Leverett.

Fig. 49, and the Geological Map will show that a ridge of greenstone passes in a diagonal manner through the Connecticut valley, forming Mount Holyoke and Mount Tom. This ridge rises in some places nearly 1000 feet above the river: and through its whole extent, it presents an almost perpendicular wall on its west and northwest sides; although several valleys of considerable depth are cut through the ridge, which is quite narrow, sometimes only a few rods upon the top. Now the geological map shows to the north and northwest of these mountains, deposits of sandstone, sienite, and granite: and bowlders of these rocks, easy to be recognized, sometimes 5 or 6 feet in diameter, may be seen perched upon the top of Holyoke and Tom;—that is, upon the trap. How they came there, is an interesting question. That they could not have been driven along the surface by water into their present position, seems quite certain; unless water could force them several hundred feet up an almost vertical wall. It may be thought that the intervening valley between these bowlders and their original bed, was once filled up, and that the bowlders were then drifted into their present position. But the period occupied by so immense a work must have been so vast, that we can hardly conceive how bowlders should still retain so much of freshness as those under consideration; and other connected phenomena, which will soon be described, impress the beholder with the comparative recency of the agency by which they were produced. Upon the whole, the mind resorts to the hypothesis, as most satisfactory, that these bowlders were transported upon icebergs, although not free from difficulties.

But these same bowlders of sienite, sandstone, and trap, are scattered all the distance, on the eastern slope of the trap ranges, from South Hadley to

Hartford, and even farther south. In West Springfield I measured one whih is 7 feet by 9; and smaller ones are very abundant. All these must have been brought over the top of the trap ridge. I confess that it seems difficult to believe that all this work was accomplished by icebergs; especially as we find the masses decreasing in size as we go south, until near Long Island Sound they are rarely more than pebbles. But I know not of a more plausible explanation of the phenomena.

There are other very interesting marks of aqueous agency upon Holyoke and Tom: but they belong to another division of the subject.

An instructive example of bowlders, showing the necessity of great caution in the examination of diluvial phenomena, occurs on Mount Toby, in Sunderland. This is an insulated and venerable pile of mountains, rising nearly 1000 feet above Connecticut river; and is composed of sandstone and very coarse conglomerate. The latter occupies the greater part of the upper portion of the mountain. Over its top we find numerous bowlders of gneiss, from one to several feet in diameter: and as this rock occurs a little to the northeast of the mountain, in Leverett and Montague, I had supposed the current here must have had a direction a few degrees west of south. But on examining the conglomerate, which forms the upper part of the mountain, I find that the imbedded fragments correspond very well with these bowlders; and in some spots we witness the process of disintegration going on. All these bowlders, therefore, may have thus originated: and although, I doubt not that some of them were drifted from a distance by diluvial agency, yet the facts stated will prevent our distinguishing those of disintegration from those properly diluvial. Were the whole of Massachusetts like Toby in its constitution the study of diluvium would be an almost hopeless task.

The montainous region west of Connecticut river, is not perhaps as fertile in diluvial phenomena, as some parts of the state, until we get into Berkshire county. This is chiefly because the rocks are slaty; and such rocks are not apt to be found in the form of rounded bowlders, unless it be some of their harder parts. As we approach Berkshire county, however, we meet with a very instructive example of bowlders. By looking at the maps and sections, it will be seen that Hoosac Mountain, especially on its western side, is one of the most distinct mountain ridges in the state. It rises at least 2000 feet above the ocean; and from 1000 to 1500 above the valleys of Berkshire: while towards the east, it consists of successive and irregular ridges and peaks gradually lower and lower till we reach the valley of Connecticut river. In the valleys of Berkshire, it will be seen that deposits of quartz rock extend across the whole state, and into the neighboring states of Vermont and Connecticut. Most of these deposits are several hundred feet lower than Hoosac mountain:—though Bald Mountain, in Clarksburg, is nearly as high; but it is separated from the Hoosac range by a deep valley. Nearly the whole distance from the north to the south line of the state, a deposit of quartz exists at the western base of Hoosac mountain; and perhaps it might once have been much higher than it now is.

Now it might be expected that bowlders of quartz rock would resist, better than those of most other rocks, both chemical and mechanical agencies, tending to destroy them: and such is the fact in the present case. Over the whole broad eastern slope of the Hoosac range of mountains, and even throughout the whole extent of the valley of Connecticut river, in Massachusetts and Connecticut, we find rounded quartz bowlders. It is common

to find them, though not large, at least 50 miles from any ledge now existing of this rock. As we rise towards the summit of Hoosac Mountain, and therefore, come nearer the place from whence they were drifted, their number and size increase. Indeed, it is not unusual to meet with these bowlders from 6 to 10 feet in diameter, which have been drifted over that mountain. As we go down the western slope of the mountain, their number and size become very great; just as we should expect, if that mountain, at the time of their dispersion, opposed itself, as it now would, to their southeasterly movement. For it will be seen that their drift must have been nearly in that direction, so that the diluvial current in the western part of the state, must have deviated farther by 20° or 30° from the meridian, than in the central and eastern portions of the state.

Another fact leads to the same conclusion. In almost every part of the valleys of Berkshire, we meet with bowlders, not usually large, of graywacke. Now if we cross the lofty and precipitous Taconic range of mountains, that bounds these valleys on the west, we shall strike a deposit of that rock in New York, extending along nearly the whole western boundary of New England. There can be no doubt, therefore, whence these bowlders were derived; and their direction must have been nearly southeast. But evidence of this statement still more satisfactory will soon be presented.

In the mountainous region west of Connecticut river are numerous and very extensive beds of serpentine. And almost uniformly we find a train of bowlders of serpentine extending southerly from these beds and decreasing in numbers and size. The same is true in fact of all the different sorts of rocks in the state: and I have mentioned only those which are easily distinguished from others, that thus other persons may be able easily to test the truth of my statements.

### 4. *Diluvial Denudation, as shown in smoothing, scratching, and furrowing the rocks, and producing valleys.*

If such vast quantities of gravel and bowlders as have been described, have been driven over New England by aqueous agency, we should naturally enquire whether any traces of such an event remain upon the surface of rocks in place. For unless these heavy bowlders were floated above the surface, they must have worn down its saliant parts, and ploughed out valleys where the force of the current was strongest. It may be doubted, however, whether even if such erosion has taken place, all traces of it may not ere now be obliterated by the subsequent disintegration of the surface of rocks by atmospheric and other alluvial agencies. Examination will show that this is often but not always the case. On those rocks which are most easily disintegrated, I have rarely met with traces of diluvial action. Only

in one or two instances have I found grooves upon the lime-stone of the valleys of Berkshire: and this rock, it is well known, is easily worn away. But on the hard limestones of the western part of New York, these marks are most striking and common. The coarse granite almost every where, and the granitic gneiss of Worcester county, show usually few marks of this abrasion. Probably no rock is less liable to disintegration than argillaceous slate: and that mica slate and talcose slate which approach clay slate; and on these rocks are the freshet and most frequent diluvial marks. Many varieties of sienite have suffered but little disintegration: and the graywacke of the eastern part of the state, as well as the sandstone of the Connecticut valley, have preserved these markings very perfectly. Even the coarsest conglomerate, whose pebbles are deeply worn down, exhibit them in a striking manner. But on all these rocks they are the freshest where they have been covered by soil. Hence it is, that excavations for roads and canals are the best places for discovering them. And I cannot doubt, but that if their entire surface were denuded of its soil, these sketches would be found on every variety of rock; and I had almost said, over the entire surface that was not protected from diluvial action.

The first effect of this aqueous agency which I shall notice, is the smoothing and rounding of the surfaces and saliant angles of the fixed rocks. These effects are the least striking of any produced by diluvial action; because, when men see a smooth rock, or one with its protuberances worn off, they rarely think of any agency except those now in operation as the cause. But in a multitude of instances, I am persuaded that these effects are the fruits of diluvial action: first, because it is only the northern exposure or the horizontal surfaces of ledges that are thus worn down; and secondly because the denuded surfaces are often situated where none but diluvial agency could have reached them. Nor are the angles rounded off by mere exfoliation, as often takes place: for the new surface is smooth, not rough as it would be if this latter agency had produced it. Where no subsequent disintegration has taken place, the surface is almost as smooth as if polished. But where it has been long exposed, more or less of erosion has usually occurred; so that if it be desired to find the most perfect examples, the rock must be uncovered where the soil is several feet deep.

So common is this appearance, that I have not thought it necessary to point out particular spots. Perhaps the sienite on the north and south of Boston exhibits it most strikingly, where it is not easily disintegrated. Often the greenstone there, as well as in the valley of the Connecticut, shows it distinctly if the soil be removed: but where exposed, this rock usually becomes rough and covered with lichens. But upon the whole, this effect is seen to most advantage upon the coarse conglomerate, both of the graywacke and the new red sandstone; because the variagated aspect of the surface renders it more striking.

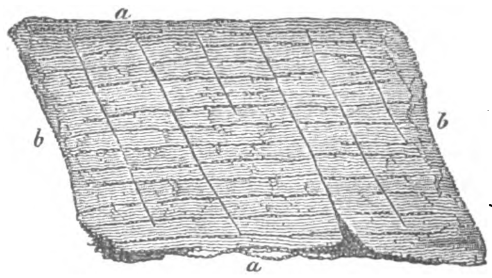
After all, it is unusual to find a large surface smoothed without exhibiting also scratches or grooves, more or less distinct. Scratches appear to have been produced by the angle of a single bowlder, driven over the surface: but grooves or furrows were the result of the passage of numerous fragments along the same track. These traces, however, are so nearly related that I shall not attempt to separate them in pointing out the localities where they may be seen. Some preliminary statements seem desirable, before giving these details.

As a general fact, it may be stated that these scratches and grooves occur either upon a horizontal surface, or upon one sloping a few degrees to the north, or northwest. I have seen them in a few instances where the slope was very gentle towards the southeast: as on the road leading from the middle of the town of Windsor towards Cummington, before it begins rapidly to descend. In all cases where the southerly slope is at all steep, no trace of these impressions appears. On the contrary, where the ledge is steep upon the north side, that face of the rock is deeply worn, often several feet below the top, much more than upon the top; as if a succession of blocks of stone had been driven violently against it, and at length dragged over the top. Where the inclination of the rocks is as great as 20° or 30°, I have sometimes seen its surface deeply furrowed as many as 10 or 15 feet below the top, and all the way to the top. Where the slope is more gentle, the grooves commence on the north side from 100 to 200 feet below the top: as on the west side of the Taconic range of mountains, and on the hill in the east part of Peru, on the road leading to Worthington: also in the west part of Worthington on the road to Middlefield: also on the north side of Mount Everett, in Mount Washington. If the rock has a very steep face on its east or west side, that face is sometimes scratched and smoothed as the rocky banks of a river are sometimes smoothed and scratched by masses of floating ice during floods.

A person unaccustomed to observe diluvial markings, may confound them with several other phenomena. The surface of rocks is often unequally disintegrated in the direction of the planes of stratification, or of the joints, in consequence of the unequal hardness. Veins of segregation also, sometimes produce the same appearance; and ripple marks are somewhat analogous. To avoid errors from this source, it is best (and I have adopted this course in the following statements,) not to consider any scratches or grooves as diluvial, that coincide with the strike of the strata, joints, or segregated veins. In most cases, however, the markings are so plain and so obviously the effect of running water, that such precaution is unnecessary to avoid mistakes.

In nearly all the cases mentioned below, the diluvial furrows make as great an angle with the strike of the strata as in Fig. 80, which was taken from the surface of gneiss in the town of Billerica, on the turnpike from Boston to Lowell; not far from the sixteenth milestone from Boston. The strata run in the direction *a*, *a*, and the diluvial scratches in the direction *b*, *b*.

Fig. 80.



In the following table, the direction of the grooves and scratches is given, as determined by the magnetic needle; which in Massachusetts at this time has a westerly variation of about 8°. I shall begin at the eastern part of the state and proceed westerly.

| *Locality.* | *Rock.* | *Direction.* | *Remarks.* |
|---|---|---|---|
| Kent's Island, Newbury, | Metamorphic Slates, | N. W. and S. E. | |
| Newbury, | Sienite, | do | In 50 places. |
| Essex, | do | do | |
| Marblehead, N. W. part, | do | N. 10° W. & S. 10° E. | |
| do west part of village, | do | do | Very deep. |
| do in town, | do | Nearly the same | Near the residence of the late Hon Wm. Reed. |
| Saugus, near the center, | do | N. 20° W. & S. 20° E. | |
| do west part, | do | do | Several places. |
| Towards Stoneham, | do | do | do |
| Woburn, | Greenstone, | do | 2 Examples. |
| Rowley, | Sienite, | N. W. & S. E. | Grooves partly scaled off. |
| Bradford, 2 miles S. E. of center, | do | N. 30° W. & S. 30° E. | |
| Dorchester, on the common near Dr. Harris' Meeting House. | Graywacke Conglomerate, | N. & S. nearly | An interesting case. |
| do in almost all parts of the town, | do | do | |
| Cohasset, N. part, | Sienite, | S. a few degrees E. | |
| do center, | do | N. & S. nearly | |
| Hingham, N. W. part of village, | do | N. and S. | |
| Scituate, W. part, | do | do nearly | |
| New Bedford, 4 miles W. of town, | Gneiss, | S. 20° E. & N. 20° W. | 2 inches deep. |
| Duxbury, S. W. part, | Granite, | S. 15° W. & N. 15° E. | |
| On the Plymouth Turnpike in various places in the towns of Quincy, Braintree, Weymouth, and Abington, | Sienite, | N. 15° to 20° W. & S. 15° to 20° E. | |
| Randolph, Canton, Sharon, Dover, Hanover Four Corners, &c. very common, | Sienite, and Granite, | N a few degrees W. & S. a few degrees E. | Exact direction not measured. |
| Dedham, half mile S. of Court House, also S. part town, | Sienite, | N. 10° W. & S. 10° E. | |
| Fall River, east of village, | Granite, | A few degrees E. of S. | Numerous. |
| do on a large bowlder, | Graywacke Conglom. | S. 20° E. & N. 20° W. | An unique case. |
| Newport, R. I. S. E. part, | do | S. 10° to 20° E. &c. | |
| Norton, village, Dr. Bates' garden, | Graywacke, | N. 15° W. & S. 15° E. | Distinct. |
| West Wrentham, west of M. House, | Red Slate & Conglom. | do | Depth 4 or 5 inches, numerous and fine. |
| Medfield, 1 1-2 mile towards Sherburne, | Sienite, | N. 10° W. & S. 10° E. | Numerous. |

| *Locality.* | *Rock.* | *Direction.* | *Remarks.* |
|---|---|---|---|
| Natick, | Sienite, | N. 20° W. & S. 20° E. | Numerous. |
| Newton west part, | Graywacke Conglom. | N. a few deg. W. &c. | Common. |
| Between Andover and Boston, | Sienite, | do | Frequent. |
| Burlington, near M. House, | Gneiss, | N. 15° W. & S. 15° E. | |
| do on road to Bedford, | do | do | do |
| Andover, Soapstone quarry, | Hornblendic Gneiss, | N. 10° W. & S. 10° E. | Distinct. |
| do 1 1-2 mile east of Seminary, | Gneiss, | do | |
| do 1 mile north of Seminary, | do | do | 2 Examples. |
| Dracut, | Hornblende Rock, | S. a few degrees E. | |
| Lowell, in and around the city, | Gneiss & Mica Slate, | S. 10° E. & N. 10° W. | Abundant. |
| Lexington, west part, | Sienite & Greenstone. | S. 5° E. & N. 5° W. | 6 Examples on the road to Concord. |
| Tyngsboro, in the village, | Gneiss, | do | Distinct. |
| Westford, 1 mile north of M. H. | Mica Slate, | Nearly N. & S. | do |
| do west of M. H. foot of large hill. | do | S. a few degrees W. | do |
| Harvard Slate Quarry, | Argillaceous Slate, | do | Very fine. |
| Pepperell, | do | S. a few degrees E. | Several. |
| Sutton, S. E. part eastern slope of hill, | Gneiss, | N. & S. nearly | |
| Worcester to Berlin, | M. Slate & Gneiss, | do | Numerous. |
| Princeton, near old M. House, | Gneiss, | S. a few degrees W. | Distinct. |
| Top of Wachusett, west side, | do | N. & S. nearly | Much weathered. |
| South Brookfield, a little E. of M. H. | do | N. a few deg. W. &c. | |
| Rutland, near M. House, | do | Nearly N. & S. | |
| Westminster, 2 miles south of M.H. on the road to Hubbardston at a cross road, | do | N. 5° W. & S. 5° E. | A fine Example. |
| Royalston, 1-2 mile W. of village. | do | N. 10° W. & S. 10° E. | |
| do E. part road to S. Royalston, | do | N. a few degrees W. | |
| do S. part high hill, | do | do | |
| South Royalston, near beryl locality, | do | N. and S. | |
| Athol, N. E. part high hills, | do | do | Frequent. |
| Petersham, by M. House, | do | N. 30° W. & S. 30° E. | Distinct. |
| Warwick, S. E. part near bed of iron ore | Mica Slate, | N. 5° W. & S. 5° E. | Sometimes several feet wide and a foot deep. |
| do near M. House. | Hornblende Slate, | do | |
| Mount Holyoke and Tom, | Greenstone, | N. & S. nearly. | Remarkable. |
| Granby, N. part, | Sandstone, | do | |
| Deerfield, S. E. part, | Conglomerate, | do | |
| Sunderland, N. part near Cavern, | do | do | |
| Montague, S. part, | do | do | Frequent. |
| Northfield, W. side of the river, | Hornblende Rock, | do | Near Hon. S. C. Allen's. |
| do S. part of village, | Conglomerate, | do | Distinct. |
| Monadnoc Mt. N. Hampshire 3200 feet high, | Gneiss, | do | Very Striking. |
| Greenfield, N. part of Federal St. and 1-2 mile N. E. of center, | Red Sandstone, | do | Very distinct. |
| Deerfield, N. W. part, | Mica Slate, | do | |
| Shelburne, N. W. part, high hill, | do | do | |
| Heath, near the center, high land, | do | do | Frequent. |
| Rowe, near M. House and in W. part, | do & Talcose Slate, | do | Sometimes 2 to 12 inches wide and several deep. |
| do do | do | N. 10° E. & S. 10° W. | Sometimes on a slope of 10° southerly, & a still greater northerly slope. |
| do N. part, road to Whitingham, spot nearly as high as Hoosac Mt. | do | N. & S. nearly. | |

| *Locality.* | *Rock.* | *Direction.* | *Remarks.* |
|---|---|---|---|
| Florida, Hoosac Mt. 2400 feet high, | do | N. 70° W. & S. 70° E. | East side of the Mt. |
| do do do | do | do nearly | West side of Mt. |
| Windsor, N. W. part, | do | N. & S. nearly | |
| do 3 miles E. of center, | do | N. W. & S. E. | Numerous & distinct. |
| Peru to Worthington, N. W. slopes, | do | do | Very striking. |
| Worthington, W. part, | do | N. 30° W. & S. 30° E. | |
| do road to Middlefield, | do | do | 300 ft. below top of hill. |
| Middlefield, near M. House, | do | do | |
| do half a mile more south, | do | N. several degrees W. | |
| do near soapstone quarries E. part, | do | do | |
| Blanford, 1-2 mile N. of M. House, | do | N. & S. nearly | Striking not measured accurately. |
| Otis to Becket, | Gneiss, | N. W. & S. E. | Several. |
| Becket, E. part, | do | do | do |
| Middle Granville, 1 mile W. of M. House, | Gneiss, | N. 30° W. & S 30° E. | Fine Example. |
| Tyringham, Mt. east of Hop Brook top, | do | N. W. & S. E. nearly | |
| Mt. Washington, W. side of Mt. Everett, | Mica Slate, | N. 10° W. & S. 10° E. | Common. |
| Mt. Everett in do. on top, 2600 ft. high, | do | do | Much weathered. |
| Egremont, W. Slope of Taconic Mt. | Argillaceous Slate, | N. W & S. E. | Distinct. |
| Copake, N. Y. W. side of Taconic Mt. | do | N. 15° W. & S. 15° E. | |
| Egremont, near Brown's Marble factory, | Limestone, | N. W. & S. E. | |
| Western slope of Taconic Mt. near the top, across the whole state, | Talcose Slate, | do | Very distinct and extending down the slope some hundreds of feet. |
| Tom Ball in Alford, on top, | do | N. 35° W. & S. 35° E. | Distinct. |
| Lenox Mt. road from Richmond to Lenox, | Mica Slate, | N. 30° W. S. 30° E. | Numerous & distinct. |
| Pittsfield, W. part on the Taconic east slope, | Talcose Slate, | N. W. & S. E. | |
| Saddle Mt. E. Valley in Adams, N. end, | do | do | |
| do do do S. end, | do | N. and S nearly | In the Tunnel. |
| do N. part of central ridge, | do | N. W. & S. E. | Cleared land. |
| do S. W. part Bald Mt. | do | N. and S. nearly. | Much Weathered. |

It would have been easy to have enlarged the preceding table: For in almost every part of Massachusetts, where I have seen the rocks newly uncovered of soil, diluvial scratches and grooves appear. But such a general uniformity prevails in their direction and appearance, that I frequently became weary of measuring and registering them; especially as I conceive I have preserved enough, out of the multitude which I have observed, to answer all the purposes of science. I have given above, two or three a little beyond the limits of the state; and perhaps it may be well to add a few others, which I have noticed. Over all the region between Massachusetts and Hudson river, they are common upon the graywacke and slate, and their average direction is N. W. and S. E. I have noticed them in Hillsdale, Dover, Nassau, Schoodack, Copake, &c On Canaan Mountain, in Connecticut, their direction, on Mica Slate, is only a few degrees west of north and east of south. The same is true near the meeting house in Norfolk, and upon the high mountain called Mount Tom, in the west part of Litchfield, they run from N. 10° to 15° W. to S. 10° to 15° E. on gneiss.

Some of the cases mentioned in the preceding table will need additional description.

Several examples are given where the grooves are quite deep, as in Marblehead near the west part of the village; four miles west of New Bedford; in West Wrentham, Warwick, Monadnoc, Rowe, and especially on Mount Holyoke. In all these cases the abrading agency appears to have operated long enough to wear out troughs several inches, and sometimes several feet, deep. Usually in these cases the ledge presents a steep slope on the north side, and the grooves commence several

feet below the top. That in New Bedford, however, is on a level surface. In West Wrentham the red slate and conglomerate, a little west of the new meeting house, show numerous markings and grooves remarkably distinct and fresh; as this is a rock that disintegrates but very little on the surface. The example in Warwick is on a hill, probably 1000 feet or more above the ocean, and near the beds of magnetic iron ore that have been described in the first part of my Report. The grooves are sometimes a foot deep, and several feet wide: and two large bowlders, weighing several tons, lie directly within the troughs; showing most distinctly the agency by which they were scooped out. I do not recollect having seen any other case of this sort so striking. I noticed these troughs in two places in Rowe; one near the meeting house, and the other in the west part of the town, on the road to Monroe.

I have referred to Monadnoc for an example of diluvial furrows, although a little beyond the limits of the state; because it appears to be a very striking case, and may aid us in forming a correct theory of diluvial action. I am indebted for the history of this example to my Assistant, Mr. Abraham Jenkins, Jr. who is well acquainted with similar phenomena in Massachusetts, and may, therefore, be relied upon. On the sides of, and around this mountain, diluvial grooves and scratches are common; having a direction about N. 10° W. and S. 10° E. The summit of the mountain, which rises in an insulated manner to the height of 3250 feet, is a naked rock of gneiss of several acres in extent, and this is thoroughly grooved and scored. One groove measured 14 feet in width, and 2 feet deep; and others are scarcely of less size. Their direction at the summit, by a mean of nearly 30 measurements with a compass, is nearly north and south.

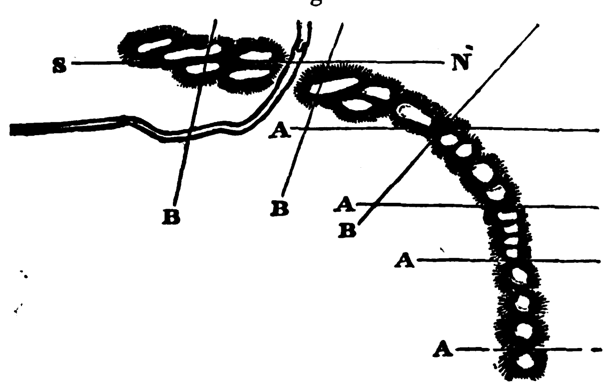
Many of the grooves on Mount Tom and Holyoke are like those already described; being only a few inches deep and wide. Such cases may be seen a few rods north of the Prospect House on Holyoke; and some distance southerly are bowlders of granite and sandstone, several feet in diameter, lying upon the spot where they have scored the trap rock in place. But most of the furrows on these mountains are worn so deep, as to become valleys, from a few feet to one or two hundred feet deep. As this is a remarkable and almost unique case in Massachusetts, it will require a particular description.

By consulting the sketch of the valley of the Connecticut on Fig. 49, it may be seen that an almost continuous ridge of greenstone commences with West Rock at New Haven, and runs through the valley to Northampton, where it crosses the river and curves off to the right, between Hadley and Amherst, forming Mount Holyoke, and terminating in Belchertown as it strikes the primary rocks. That part of the mountain in Northampton is called Mount Tom, which sinks several hundred feet abruptly near the south line of the town, and between it and Holyoke there is a gulf, but little wider than is necessary to allow the river to pass. Tom rises about 1000 feet above the ocean; but Holyoke not more than 900 feet: yet the top of the ridge is of exceedingly unequal elevation; being crossed by a multitude of valleys, varying in depth from 8 to 10 feet, to that in which Connecticut river runs; which is at least 800 feet below the highest part of the ridge. The upper part of the mountain is composed of greenstone, which rests on sandstone; and in several instances the greenstone has been all swept away in the valleys above named, so that their bottom is only sandstone. But in general, the valleys are not deep enough to reach the bottom of the greenstone. It ought further to be remarked, that on its west and north sides, this ridge is very precipitous, at least for 200 or 300 feet; so that in fact the upper part of it, through which the valleys have been cut, forms a wall of very hard materials. Plate 6, will give a good idea of the appearance of Holyoke and Tom, as seen from Amherst on the north side of the ridge, 5 or 6 miles distant. And yet such a drawing can exhibit only the larger valleys. After having traveled on foot from on end of the ridge to the other, not far from 15 miles, I should say that the number of distinct valleys must exceed 50; and perhaps they may amount to 100. It was not till within three or four years that I suspected them to have been

produced by the eroding action of water. Their bottoms are so covered with soil and detritus, and their sides have been so much scaled off by atmospheric agencies, that although their general aspect is precisely that of the deserted beds of streams, some more decided proof seemed wanting to establish the fact, that 50 water courses had been worn out across the top of this narrow ridge; which on the north side is almost perpendicular, and on its other side very steep. I had formerly supposed that the inequalities on its top might have been produced by the original protrusion of the trap through the sandstone: but noticing frequent grooves, as well as large bowlders, upon its top, as well as a great resemblance to ancient water courses in the valleys, I was led to closer examination, and by the following argument satisfied myself that they are valleys of erosion.

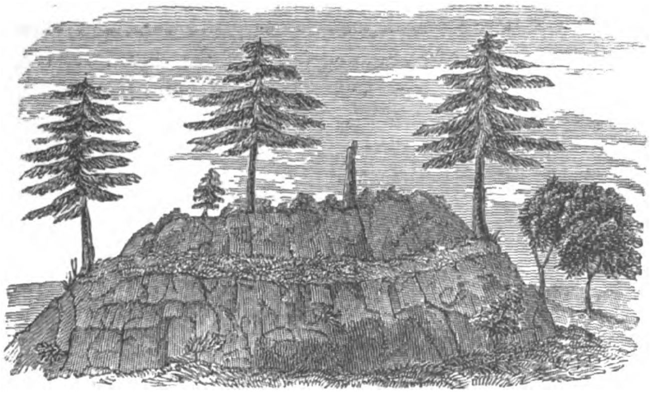
The sketch of the valley of the Connecticut, Fig. 49, shows that Mount Tom and the south part of Holyoke have the general direction of the range, which is a few degrees east of north: but Holyoke rapidly curves to the right as we pass northward, until it becomes, in its eastern part, for four or five miles, nearly east and west; or almost at right angles to the general direction of the ridge. This is shown more distinctly on Fig. 81, which represents Tom and Holyoke; the line N. S. being the magnetic meridian. The valleys are also shown upon their top, running in the same direction as they actually exist, though no attempt is made to exhibit their actual number. Now I first noticed these valleys, A, A, A, in the eastern part of the ridge, where they run nearly north and south, and cross it nearly at right angles. And before I had made farther examination, I argued, that if they were produced by the original protrusion of the mountain, as the mountain curved I should find them in every part crossing the ridge at right angles; as shown by the lines B, B, B. But if produced by that same far reaching northerly current, which has swept so powerfully over other parts of the state, the valleys would continue to have the same direction, even where the ridge runs nearly north and south. Careful examination brought abundant proof that the latter supposition is the true one.

Fig. 81.




When the ridge runs nearly north and south, however, and is only a few rods wide, we not unfrequently find a valley divided into two; one running more to the right, and the other more to the left than the usual course; while at their junction, a ridge of trap is interposed between them, whose northern extremity is rounded, as if the current had beat powerfully upon it, and by it had been deflected to the right and the left. As the trap is arranged somewhat in successive stories, having a columnar form, the appearance is that shown on Fig. 82, which was taken a little south of the prospect house on Holyoke. Berzelius describes a similar appearance on the northeast side of the mountains in Sweden, as "resembling at a distance, sacks of wool piled upon each other." This description strikingly corresponds to the case on Holyoke shown in the figure.

Fig. 82.



*Greenstone Hummock on Holyoke.*

I do not suppose that all the valleys on Holyoke and Tom were entirely produced by diluvial agency. If they were, I cannot see why some of them are so much deeper than others. Probably there were original inequalities in these mountains, and in many cases this agency only modified the valleys that already existed. The present bed of the Connecticut, between Holyoke and Tom, appears to be a valley of erosion; yet here was probably a depression in the ridge before the aqueous agency commenced. Indeed, by examining the sandstone strata beneath the trap, on the north part of Tom, and the south part of Holyoke, it will be found that they dip laterally towards the river. On the north side this is particularly obvious: so that while at the river the line of junction between the two rocks passes beneath its waters, less than half a mile north, the junction is not less than 200 feet above the river; making a dip of nearly 5°. A similar dip may be seen on the west side of Tom, by standing at considerable distance, and observing the general line of junction between the two rocks; which is made obvious by the difference in the vegetation. I infer, therefore, that the bed of this river between these mountains, was originally a valley of subsidence, occasioned by a fault in the sandstone. Probably, therefore, the actual erosion by the waters has not been much greater in this valley than in many others on these mountains. But the work here commenced at a lower level.

I have met with scarcely no examples of diluvial valleys, like those on Holyoke, in other parts of Massachusetts. The top of Toby in Sunderland, considerably higher than Holyoke, shows a few of them, which are not of much depth. The high hill south east of the village of Ware, may perhaps exhibit this phenomenon; and I thought I discovered it among the diluvial hills in the south part of Sandwich. It ought, however to be recollected, that most of the mountain ridges in the state run north and south; and this may have prevented the occurrence of those valleys. The Blue Hills, south of Boston, which run east and west, I have not found time to re-examine, since my attention was called to this subject. But a mere view of the outline will satisfy any one that no valleys can exist there that can be compared with those on Holyoke. Upon the whole, I am inclined to the opinion, that this phenomenon exists on Holyoke and Tom, because their elevation is less than that of the primary regions forming the east and the west sides of the valley, and, therefore, the diluvial waters acted there a longer time The direction of the current in that valley, as appears from the course taken by the drift and the bearing of the grooves and scratches, corresponded essentially with that of the valley. In other words, it would seem that when the level of the diluvial waters had sunk below the tops of the primary ranges, the current was diverted down that valley. While yet its force was great enough, or the materials borne along by it powerful enough, to groove the hard summit of Holyoke and

Tom, it would continue to scoop out and modify the valleys that now cross these ranges. But after its velocity had become moderate, and perhaps too the icebergs and detritus borne along by it had disappeared, then would it begin to deposit the clay and sand now found in the banks of the Connecticut and its tributaries. After the deposition of the clay, however, it would seem as if a period of greater violence succeeded in the waters, or else the materials brought along and deposited by them were coarser; since we find sand uniformly above the clay. Perhaps, however, this might have resulted from floods, by the melting of snows, or powerful rains. Indeed, it is impossible in this case to say where the diluvial agency terminated and where the alluvial agency begun.

One negative fact ought perhaps to be stated in this connection, on account of its bearing upon the theory of diluvial action. Multiplied and striking as are the marks of powerful currents of water rushing over our highest mountains, and passing through our valleys and gorges, no example have I ever seen of what are called *pot holes;* that is, pot shaped excavations made by the gyration of pebbles. In existing streams these are common wherever there is much of fall in the water over rocks. This last circumstance is, I apprehend, essential to their production; and hence we may infer that diluvial action was not the result of rivers, but of a wide spread current in which falls of much magnitude could not occur.

A few other cases of diluvial grooves and scratches that have been given in the preceding table, deserve description.

The case in Rowley illustrates the comparative recency of diluvial action. There, on one part of the sienite, the grooves are distinct: but upon an adjoining portion, a crust of not more than an inch thick is scaling off, by which means the furrows are entirely obliterated. Hence it needs disintegration only to a very slight depth to destroy all traces of diluvial agency upon the rocks in place. Now there is no rock exposed to the atmosphere that does not disintegrate to some extent. If, therefore, this work had been performed at a period immensely remote, all vestiges of it would have disappeared from the rocks, as they have done from those most exposed, and most liable to decay. But I have often been surprized at the apparent freshness of these grooves; especially where protected by the soil. It is true that when we reckon time by tens, or even hundreds of years, this argument is of little weight; because rocks, during such periods, may suffer but little perceptible change. But when we come to compare periods of thousands of years with one another, the change cannot but be manifest, and we feel that it would not need the repetition of a very large number of such periods to bring us back to the diluvial epoch. Even though they should be multiplied ten, or twenty times, the epoch would still be recent in a geological sense.

The case in Dorchester, on the common near Dr. Harris' Meeting House, is a good example of the local deflection of the diluvial current by an obstacle. The rock here is graywaake conglomerate, and in one place the surface has a northern slope of about 20°, and is moreover arched so as to present a rounded slope on the east and west sides, forming in fact a surface like one half of a paraboloid. Hence the fairest opportunity presents itself of turning aside the current; and we find a deflection amounting perhaps to 10°. In general, however, the grooves pass almost directly north and south up the slope of 20°; and the deflection is less than we might expect. Indeed, this is the case almost every where. Crossing as the diluvial current did, a very broken

country, and making not a large angle with so many precipitous ridges, we can hardly see why it should not be turned more out of its course than it was. I have met with but few cases where the deflection was as great as in the case described in Dorchester. And I have often been amazed to see these grooves hold on their undeviating course over the roughest country. I cannot but infer from such facts that the current must have been very strong. And I also infer that at least a large part of the materials, by which these grooves and scratches were produced, moved along the surface, and not at the bottom of the waters. And yet, when I see vast accumulations of detritus just in those situations where the currents passing through defiles and valleys would have driven it along the bottom, I cannot doubt but much of it was thus removed.

There is another fact, however, that shows still more conclusively that a great deal of the drift must have been borne upon the surface of the waters: and that is, the occurrence both of the grooves and the bowlders upon the top of ridges almost perpendicular on the side from which the waters flowed; and, therefore, these bowlders never could have been driven up these declivities by the horizontal force of water. I think any man, who will go to the tops of these mountains, where occur grooves, and often bowlders of great size, will be satisfied at once that water alone never could have accomplished the Sisyphean work of driving those bowlders up almost perpendicular ledges, hundreds and even thousands of feet; although it be true that a stone loses half its weight in water. The only question will be, whether the relative levels may not have been altered since the period of diluvial action. But careful examination will soon convince him that no such change has taken place, since bowlders are often accumulated at the foot of the present ridges, just as they would be, if that action were now to take place. The mind then will be driven to the other supposition, viz. that in some way or other, many of these bowlders must have been floated upon, or near the surface of the water.

One other circumstance confirms this view. I refer to the very considerable distance below the summit of the mountain, where the grooves commence on the northerly or westerly slope; as is seen at many places on the Taconic range, on Mount Everett, on the hill between Peru and Worthington, and very distinctly on the road from Worthington to Middlefield, in the west part of Worthington. In some of these places they are first seen at least 200 or 300 feet below the summit; and the slope is at least from 10° to 30°. They extend directly towards the summit; or rather they hold on the usual course, whether it lead to the summit or not, with as much regularity as if the surface were horizontal. Could detritus have been pushed up such a declivity by the current? Are not the grooves rather to be imputed to the bowlders that were fastened to large icebergs, which, by the powerful current, were forced over the summit? This solution is not indeed free from difficulties: but is there any more probable substitute.

Some will perhaps impute these scratches to mountain slides, or avalanches. But in that case the detritus ought to be found at the bottom of the hill; whereas it is carried over the hill: And besides, the groves often pass obliquely along the slope of the hill; whereas an avalanche would always take the nearest, that is, a direct route to the bottom.

There is one other unique case mentioned in the table that deserves some notice. It is the only example of the kind with which I have ever met. On the east side of Taunton river and the south side of Fall River, I believe just within the limits of Rhode Island, there lies a bowlder of coarse graywacke conglomerate, nearly 50 feet in diameter, which was formerly covered by at least 10 feet of diluvial gravel, that has recently been removed, as well as a part of the bowlder. Now this block must have come from the opposite side of Taunton river, or from several miles north; where alone a similar rock occurs in place. But after it had been transported to the spot which it now

occupies, it seems to have resisted all efforts to remove it farther south: either because it found the bank an obstruction, or the current was less violent. At any rate, after it became planted, the detritus which was subsequently forced over it, began to wear down its top, and to cover its abraded surface with diluvial scratches and furrows. The surface has been abraded several feet, and the marks remain quite distinct, running N. 20° W. and S. 20° E. Such inroads have been made upon this bowlder by the quarrymen, that I fear this curious example will soon disappear.

*Results as to the Direction of the Grooves.*

If we attempt to generalize the facts that have been given as to the direction of diluvial grooves and scratches in the state, we shall arrive at the following conclusions. Upon the Map which shows the strike of the strata, the varieties in the direction of the diluvial grooves are presented to the eye.

1. In all the eastern part of the state, except the northern part of Essex County, the direction is about 15° W. of N. and E. of S. by the magnetic meridian, and a little over 20° by the true meridian.

2. In Essex County the course is nearly N. W. and S. E. by the compass, and about 8° farther from the true meridian.

3. In all the central parts of the state, as far west as the west side of the valley of Connecticut river, the direction varies from the true meridian from 8 to 13°, westerly at the north end, and easterly at the south end. One case is recorded in Royalston, where the course is N. 18° W. and S. 18° E. and another quite remarkable one in Petersham, running N. 38° W. and S. 38° S. I can assign no local cause for this deviation from the usual course. In Princeton an example is mentioned, where the course is not far from true north and south. But there the deflection is easily accounted for by the proximity of Wachusett mountain. Similar examples exist on Mount Holyoke, where in fact the course is sometimes even N. a few degrees E. and S. a few degrees W. of the meridian. But here the deflection is evidently occasioned by the general direction of the valley; and yet it is changed only a few degrees from this cause.

4. On the mountains of Berkshire county, the course is N. nearly 50° W. and S. 50° E. of the true meridian. One case is recorded in Florida where the course differs only 12° from true east and west. On the other hand, several examples are given where the direction is but a few degrees divergent from the meridian; as in the north part of Rowe and Windsor, and upon the southwest part of Saddle Mountain, on the part called Bald Mountain, and in the Tunnel on its eastern part. In Mount Washington and on Mount Everett, the course is only N. 18° W. and S. 18° E. The cases on Saddle Mountain are easily explained by local causes of deflection; in other words, by the effect of the central part of the ridge upon the diluvial current. But

the other cases are more difficult thus to dispose of. However, one cannot traverse the western part of this state and the eastern part of N. York, without being satisfied that the general course of the diluvial current over that region was nearly from N. W. to S. E.

5. The most important enquiry suggested by the facts that have been stated, is, whether one general diluvial current might have produced all the grooves in Massachusetts, or whether we must suppose several currents at different periods, running in different directions. I am rather inclined to the former opinion; though not confident of its correctness. My reasons are the following. 1. The grooves on our highest and most insulated mountains do not differ much in their direction; those for instance on Wachusett and Monadnoc running about 8° or 10° W. of N. and the same E. of S: and those on Mount Everett, and in other parts of Mount Washington, as well as upon Canaan Mountain and Mount Tom in Litchfield, Connecticut, running N. 18° W. and S. 18° E. 3. This may be owing to the fact that when the diluvial waters were the deepest, they were less deflected by the inequalities beneath. 4. The direction of the current may have been different at the surface and at some depth beneath; where the inequalities of surface may have affected it. 5. The general uniformity of direction in particular districts of the state indicates some local cause of deflection. For had the grooves in these districts been the result of diluvial action at different periods, we should expect the grooves produced at various times would be found in the same district. This is in fact somewhat the case in the western part of the state: But it must be recollected that this is the most broken part of the state, and therefore, most likely to deflect the current. 6. The diversity of direction is not perhaps greater than we might reasonably expect in so wide a current. 7. If produced at different epochs, with much interval between them, we should expect that the different sets of grooves would exhibit marks of greater or less antiquity. But I have never seen any such difference, where the surface had been equally protected, and the rock was the same. 8. It may be that the diluvial waters poured over the surface in successive waves, and that these might not have been impelled in the same direction. Or those waters might have risen, and then subsided, and then have risen again. And I confess that without some such supposition, I know not how to explain all the appearances.

Notwithstanding these arguments, when I come to enquire in respect to particular districts of Massachusetts, why the diluvial current there had a different direction from its course in another district, I am usually at a loss to assign any adequate cause. Why, for instance, was it several degrees different in Essex county from what it was in Bristol and Worcester: and especially, why should it have rushed over the Taconic mountain in a direction so much east of south? I do not see any cause in the topography of

**the country. In the latter case certainly, I should have expected the deflection to have been rather towards, than from the meridian. For these reasons I feel incompetent fully to solve the problem under consideration.**

It is difficult to reason correctly concerning the causes of diluvial agency in Massachusetts, without knowing something of the same agency in other regions of our country. But in this place it will be necessary only to state a few general facts, reserving the details for the last part of my report. Suffice it to say, that the country, on a line from the eastern part of Nova Scotia, nearly to the Rocky Mountains, or as many as 2000 miles, has been examined so far as to prove conclusively, that diluvial action, similar to that in Massachusetts, though not in all places so striking, has taken place throughout the whole distance. In other words, a powerful current of water has passed over all this region from the north, or more accurately, from the northwest. On the eastern continent a similar current has swept over the north part of Europe, at least from Netherlands to Moscow, or 1500 miles, in a southwesterly direction.

A curious example, perhaps connected with diluvial agency, has just been brought under my notice (Sept. 1840,) by the excavations that are going on upon the Western Rail Road, in the south part of Middlefield. The road there passes through two ridges of hornblende slate, whose strata stands at right angles to the horizon. The most westerly ridge is not yet gone through, and the west end of the excavation has the appearance exhibited on Fig. 83. below. The ledge is covered by 20 feet of diluvium. And for for 8 or 10 feet below the top of the ledge, the solid rock appears to have been extensively fractured by some heavy blow upon the surface of the rock, directed southerly. The effect has been to break the rock more or less, and produce fissures more or less horizontal, from one to five or six inches wide, as shown in the figure. These are now filled with sand, and sometimes with regular layers of clay. The layers of rock, also, are bent southerly several degrees, just as they might be by a powerful shock given them in that direction. The sand and clay have probably been infiltrated since the fissures were made. I know of no natural agency, except diluvial action, that could have produced such an effect. Yet I shall describe another case in a subsequent part of this report, where the top of a hill of slate is bent in a similar manner: but the direction does not correspond with that of the diluvial current: and hence I have given the above case, not without suspicions that I may have referred it to the wrong agency.

Fig. 83.

Before enquiring into the ultimate causes of diluvial action, let us see what legitimate inferences we can draw from the phenomena as they have been detailed in this country, especially in Massachusetts.

1. The highest parts of New England, and in fact all the northern parts of our continent, have been swept over by a powerful current from the northwest to the southeast. I am not able to say whether the very summit of Graylock, the highest point in Massachusetts, shows the marks of this current. Nor have we yet had a report from the White Mountains, the highest point in New England. But many other points nearly as high, bear these marks most strikingly; and if we must still except these, we are sure that every other part of this region of hills and mountains has been overtopped by the diluvial waters. In Massachusetts we have Mount Everett, not less than 2600 feet high, and Wachusett 3000 feet high, and in New Hampshire, Monadnoc, 3250 feet high, all bearing marks of powerful erosion, and all of them standing as insulated peaks, hundreds of feet above the surrounding country; and in Maine, Dr. C. T. Jackson describes Mount Ktaadn as showing diluvial action on its summit, which is 5300 feet above the ocean.

2. The diluvial waters must have been oceanic. What other aqueous agency could have produced a current 2000 miles in width, I am unable to conceive. The present rivers that drain the surface, never could have left such an appearance: much less could their united waters have deluged our continent. Some geologists have, indeed, attempted to explain diluvial phenomena, by supposing an immense inland sea to have once occupied the valley of the Mississippi, which is bounded on the east by the mountains of New England. (*Mr. Hall in the Report of the N. York Geologists for* 1839, *p.* 432.) They suppose one of the outlets of this sea to have been the valley of the Connecticut, whose head is not more than 1000 feet above the ocean, and that by this current the rocks of New England have been driven across Long Island Sound, and planted upon the Island. But admitting all this, which it would be easy to show erroneous, how will the drainage of this inland sea explain the powerful erosion of such mountains as Mount Everett, Saddle Mountain, Tom Ball, Monadnoc, Wachusett, and Ktaadn? whose tops are some thousands of feet above the barrier of the Mississippi valley on its southeastern side? How will it explain the currents of water that have swept southeasterly over all New England, almost without reference to its valleys, and even over Nova Scotia? How will it explain the transportation of the bowlders southerly from the primitive rocks of Canada, over the Western States? It appears to me that we are fully warranted in regarding the waters that did all this as oceanic.

3. There is no reason to suppose that the inequalities of surface, which now exist, were essentially different at the epoch of diluvial action. Minor

changes were, indeed, produced by that action, as well as by subsequent alluvial agency. But the great outlines remain unchanged. For we find the bowlders to have been obstructed, just as they would have been, if the present mountains then existed: and in some cases the current was deflected as it would be now. But the fact that has struck me as most decisive on this point, is this: Where large surfaces—often several square rods, and sometimes many acres—are smoothed and scratched, I have never seen any evidence of a change in the relative levels of different portions of that surface. Now as numerous fissures cross the surface thus smoothed, if there had been any local elevation in the vicinity, it is incredible that there should not have been some elevation or depression of such surfaces, so that one part should rise above other parts. But I have never seen any such inequality of the smoothed surface, even to the amount of half an inch, except what has been produced by alluvial agency. In short, all such surfaces appear as if they had remained unaffected by any vertical movements since the period of diluvial action, unless that movement affected the whole country alike; that is, unless the continent was raised up, or sunk down, as a whole. In like manner, if local vertical movements had succeeded diluvial action, those elevations of gravel and sand, so common in New England, must in some instances have been disturbed. But there is a freshness about them that is remarkable. They still retain the marks of the gyrations of the last wave or current that passed over them.

4. Diluvial action in New England appears not to have taken place till the continent had been raised nearly to its present height above the ocean. The counter supposition is, that it took place when the present surface formed the bed of the ocean, or was gradually rising above it. Now that this cannot have been the case, I argue in the following manner.

No rocks in Massachusetts, or any other part of the United States, except alluvium, lie above the diluvial deposit. Consequently diluvial action took place after all others had been formed. Of the fossiliferous rocks we have in Massachusetts the graywacke of the eastern part of the state, with anthracite coal and coal plants; the red sandstone of Connecticut river, containing plants, some of which appear to be dicotyledonous; and the plastic clay of Martha's Vineyard, which I have referred to the eocene tertiary: and which no one certainly will consider older than the cretaceous group. That dry land existed in the vicinity, when all these rocks were in the process of deposition, is certain from the fact, that they contain the remains of land plants.

bottom of the ocean, we ought to find no traces of it upon our primary mountains, which were already above the waters. But further, it did not take place till all the secondary and tertiary rocks above named were tilted up, so as to have their present dip. And that this tilting process was synchronous with the elevation of the deposits to their present levels above the waters, it seems hardly possible to doubt. Hence we have strong reason to believe that all these rocks were above the ocean before experiencing diluvial action.

It will be said that the time was, when all this continent was beneath the ocean; and that then what I call diluvial action took place upon the primary mountains; and as the land rose and new formations were deposited, this agency acted upon the whole surface before it rose, or while rising, above the waters. This is, indeed, a simple and intelligible view of the subject; and I have often tried to reconcile it with the facts. But the following considerations have proved too refractory.

1. On this supposition diluvial action took place upon the primary ridges before the secondary and tertiary formations were deposited: and upon the latter not until they were consolidated. Consequently, in the opinion of every geologist, (and to such only do I address this argument,) an immense period, to be estimated only by tens and hundreds of thousands of years, intervened between the period of this action upon the oldest primary and newest secondary or tertiary strata. But the grooves and scratches appear no more fresh upon the latter than upon the former. Yet if made hundreds, or even tens of thousands of years earlier upon one than upon the other, is it credible that they should not have been wholly obliterated upon the oldest; especially when we recollect that a disintegration to the depth of an inch or two, would usually effect this obliteration.

2. According to this hypothesis, the diluvial abrasion of the rocks must have taken place before the strata had been thrown into their present inclined position. For it was that tilting up which raised them above the waters; or rather, that was sufficient to raise them; and, therefore, we ought not to call in other agencies to account for their elevation, according to a well known law of philosophizing. Or, if we might suppose the primary strata partially tilted up before they were subject to diluvial action, this could not have been the case with the fossiliferous strata, which were not deposited till after that action had begun to be exerted upon the primary strata according to this theory. Now I have already attempted to show, that the relative levels and general outlines of the surface have not essentially changed since the period of diluvial action. Certain I am, that no one, who will make himself familiar with these phenomena in New England, can believe, that since that time our different moun-

tain ridges have been successively lifted, several thousand, or even several hundred feet, from the ocean.

3. But waiving the preceding difficulties, and supposing the continent beneath the ocean, we know of no currents in our existing seas of sufficient velocity and power to produce a moiety of the effects which the diluvial currents have produced. The present currents could, indeed, transport icebergs loaded with bowlders and pebbles, at the rate of 3 or 4 miles per hour, and along some narrow friths, at the rate of 10 or 12 miles per hour; and these bowlders might be dropped from time to time along the bottom. But this is a very different thing from urging over that bottom such a mass of detritus, and with such violence, as to wear down the surface, and score it over so deeply as we find to have been done upon our rocks. But it may be said, that the breakers upon an exposed shore might have accomplished the work. They might have worn away the rocks: but they could not have produced those parallel and continuous grooves and scratches, which the more exposed surface of New England every where presents, and which hold on their course obliquely across those lofty ridges, which must have formed the shores of the ocean, as the continent gradually rose from the waters. The diluvial phenomena of our country indicate a current that swept over the entire surface, and not waves breaking against cliffs and rolling back. The latter produce very few effects at all analogous to the former. But more of this farther on.

In support of the general position, that before diluvial action took place, this continent had been elevated nearly to its present height above the ocean, I have one more syllogism to offer. That our lofty primary ridges must have been elevated so as to form dry land before the deposition of the fossiliferous strata, (graywacke, new red sandstone, cretaceous rocks, &c.) is certain; as already shown from the fact that these strata contain land plants. But that the same diluvial current that swept over the fossiliferous rocks went over the primary ridges, is also certain from the fact that bowlders of the former are strewed over the highest parts of the latter. For instance, bowlders of graywacke from New York, are found upon the highest parts of the Taconic and Hoosac Mountains: the sandstone of the Connecticut valley is occasionally found upon the primary rocks on its eastern borders: the graywacke of the eastern part of Massachusetts is strewed over all the primary ranges of that region: and bowlders of graywacke, according to Dr. Jackson, are found near the summit of Mount Ktaadn in Maine, more than 5000 feet high. Now either our primary ranges must have sunk down beneath the waters of the ocean, after having been for a long time several thousand feet above them, or the diluvial waters must have risen above them after their elevation. The former supposition will hardly be admitted by any geologist; and therefore, we are compelled to adopt the latter.

5. It is difficult to explain all the phenomena of diluvial action on this continent, without calling in the aid of icebergs, or some other agent, by which masses of rock could be floated along the surface of the waters; yet after all, those icebergs will explain but a small part of the effects of this action. I cannot conceive of any other way, except by icebergs, by which those bowlders, found many miles from their native beds, and perched upon high and almost perpendicular ridges, or dropped in the midst of sandy plains, could have been transported. But to suppose that the great mass of sand, gravel, and blocks, composing diluvium, could have been borne along by icebergs, is an hypothesis which any man would abandon as soon as he should examine that deposit, and see its amount. Then again, he would find that usually the largest and most numerous bowlders lie nearest to the rock from which they have been detached; and that the train decreases in size and number as we proceed southeasterly, except the few straggling bowlders already alluded to. Now I cannot conceive that an iceberg, lifted up by the waters from a particular spot, with bowlders frozen into its lower parts, should begin to let those bowlders fall out within a few rods from the place where it started. I should expect that in general they would not begin to fall, till the iceberg began to melt. In short, the great mass of diluvium appears as if driven pell mell along the surface by violent currents; and so does the surface over which it has been urged, whenever it can be examined. It is difficult, therefore, to explain some of the phenomena of our diluvium without icebergs; but still more difficult thus to explain the whole.

6. The phenomena of diluvial action in this country far transcend the effects of any agencies now operating, without admitting a great increase of intensity in their action. So much has been said of late years, and so ably, respecting the sufficiency of the present operations of nature to explain all past phenomena, that one cannot but feel a diffidence in resorting to extraordinary agencies in past times. But in vain have I searched for any agency now at work, that produces effects at all comparable to the effects of diluvial action. The statements of Professor John Phillips, one of the ablest living geological writers, concerning diluvial action generally, is eminently applicable to that portion of it that has fallen under my notice, in America. "Such effects," says he, "are not at this day in progress; nor, in general, can we conceive the possibility of their being produced by the operation of existing agencies, operating with their present intensities, or in their present directions." (*Treatise on Geology, Vol. I. p.* 296.) I have frequently examined the rocky shores of the ocean, and the beds of rivers where they form cataracts, or force their way through narrow defiles and gorges, to ascertain whether the effects of the powerful currents and waves of the present time are comparable to those of diluvial action: and I have always been

struck with the vastly greater force of the latter. On exposed shores, and at the bottom of gorges and cataracts, we do, indeed, find the rocks worn away; but their surfaces are usually smooth, and almost wanting in those deep and extended grooves and scratches, which are the result of diluvial action. Deep gorges do, indeed, show the process of extensive excavations. But this work is generally not so much the effect of direct erosion, as of the expansion of water in the fissures of rocks, by freezing; in consequence of which, large blocks are gradually lifted up, while the stream wears off their angles, and at length has force enough to move them from their beds, as well formed bowlders. In this and other modes of an analogous kind, I presume the largest part of bowlders have been formed, or got ready to be driven southerly by diluvial currents. But one sees at once that the two agencies have operated in a very different manner. While the excavations of gorges and the wearing away of the sea coast, have been the combined and slow result of disintegration and moderate erosion, diluvial phenomena seem to have been the direct result of mighty currents of water, loaded with detritus, and rushing over the surface with such violence as to wear down the rocks much more powerfully and rapidly: a violence that did not permit the detritus to find its way around obstacles, but forced it directly over them in a manner altogether different from the comparatively puny action of water at the present day. But after all, it is impossible so to present this subject as to make one feel it, who is not extensively familiar with diluvial phenomena.

7. The facts that have been presented respecting diluvial action, furnish a probable reason why the diluvium of this country is so destitute of organic remains. In New England I scarcely know of any of these remains, except perhaps a single example of bones of the mastodon found in Sharon, Berlin, and Cheshire in Connecticut; and a few shells in some of the diluvial clays in Maine: and not improbably in both these instances the deposits may have been alluvial. The same may be said of all the instances of organic remains in the diluvium of this country. Its almost entire want of these, so far as discoveries have yet been made, is a well known fact. And if the diluvial waters were poured down from the arctic regions, loaded with ice, we see the reason of it. Animals did not live in such waters; and we ought to expect to find in them only those animals which were then the inhabitants of this continent, and were destroyed by the diluvial waters. Whether the mastodon and other extinct races discovered in this country were then destroyed, or subsequently, does not seem to be well determined. Even the more quiet period that succeeded the early periods of diluvial action, seem to have been almost destitute of organic existence. Hence it is, that the blue clay of New England contains almost no relics of animals or plants.

It will be seen that in the preceding inferences I have not attempted to form any general theory of diluvial action, but only to state the more important independant conclusions to which the facts, with more or less of probability, conduct us. Let us now see whether these facts will sustain any of those numerous diluvial theories that have been proposed in recent times by ingenious men. I may pass by the hypothesis to which some have clung even in our own times, which imputes diluvial action to the shock of a comet; since it seems now quite certain that these bodies are in general composed of matter thinner and lighter than air.

Another theory, which has long been a favorite one, imputes diluvial action to the deluge of Noah. The freshness and apparent recency of the effects of this action and its apparent universality, give at first view a strong probability to this supposition, if we understand the language of scripture in its most literal sense. But many distinguished biblical writers regard the description of the Noachian deluge as an example of the use of universal terms with a limited meaning, and hence regard that deluge as not universal over the globe, but only over the region inhabited by man. Again, if the diluvial action of geology resulted from the deluge of Noah, why are the organic remains found in diluvium mostly of extinct animals? and why is not man among the number? Finally, the diluvial action of geology must have occupied a much longer period than the 150 days, or at longest, the year, of the Noachian deluge. It is difficult, if not impossible, to make any one feel the force of this objection, who is not familiar with diluvial phenomena. But he who has seen where the hardest rocks have been worn away many feet at least, and probably sometimes many hundred feet, by diluvial action, cannot but see that many years must have been required for the work, even though the waters were driven over the surface with the greatest violence.

These objections, are very conclusive against this hypothesis. As bearing upon the veracity of the sacred historian, however, this question I conceive can have little or no importance, since it does not prove the non-occurrence of the Noachian deluge, even though no traces be now remaining upon the earth's surface of that event.

A theory has lately been started to explain diluvial phenomena, founded on the action of glaciers in the Alps. Though not originally proposed, it has been chiefly elucidated and defended by the distinguished naturalist, Agassiz, of Neuchatel in Switzerland. That it may explain the movements of detritus in the Alps, which for the most part appears to have been carried outward from the axis of the mountain, I am not disposed to deny: and of course it would explain equally well all similar cases where slopes exist, down which glaciers may have descended. But I am unable to see how this agency could have transported detritus in a southerly direction several hundred miles, over

nearly all the most elevated ridges of this country, almost without reference to the direction of those ridges, and even have driven it upward along slopes considerably inclined, as appears to have been done on the western side of New England. Nor does it give any reason for the immense accumulation of sand, pebbles and bowlders, piled up in a fantastic manner, at great distances from any existing mountains, as in Plymouth and Barnstable counties. In the case of the Alps, it is supposed that the ridges have been considerably elevated since diluvial agency commenced; and this vertical movement would tend to scatter the detritus over a wider space. But we have no evidence that any of the high ridges of this country have been raised sensibly so recently. Certainly there is no chain of mountains on this continent whose elevation would send bowlders and gravel southeasterly over hundreds of miles. Even though the valleys were filled by ice, yet where is the force to be found to urge the detritus so far in that direction. I confess I have as yet seen only a very brief and evidently imperfect developement of this theory, in one or two short notices in the scientific journals. But as I understand it, it seems to me inadequate to explain the *tout ensemble* of diluvial phenomena.

Another theory of diluvial action supposes it to be merely ancient alluvial action. Its advocates suppose that the same causes of change, which are now in operation on the globe, have always operated as they do at present, with no more variation of intensity than they now exhibit. Diluvial action they suppose to have resulted partly from ancient rivers, which at some remote period may be supposed to have flowed at any elevation, and subsequently to have lowered their beds to their present levels. Another cause may have been the bursting of lakes: another, landslips: another, the action of breakers upon the coast, as the continents gradually emerged from the ocean: another, the tides and currents of the ocean: another, icebergs, such as now float from arctic regions and drop bowlders and sand along their track: so that when the bottom of the ocean was afterwards raised above the waters, the surface would be strewed over with detritus, as we now find it.

If I have not entirely mistaken the phenomena of diluvial action in this country, especially in New England, it will be exceedingly difficult to reconcile them to this hypothesis. The difficulties are numerous. In the first place, neither rivers, nor the bursting of lakes, nor breakers upon the coast, although they may prepare bowlders to be transported, will account for a current from 1500 to 2000 miles wide, which has swept southerly over this continent: Nor could they produce those grooves and scratches which are so common and uniform in their direction in New England. In the second place, as I have attempted to show in another place, the relative levels of the

surface have not very essentially altered since the period of diluvial action; as they must have been by this theory. In the third place, oceanic currents have not sufficient velocity to transport any thing coarser than sand along the bottom, and therefore diluvial grooves and scratches could not have been thus produced. In the fourth place, although icebergs might have transported some bowlders, they could not have conveyed the great mass of diluvial detritus into its present situation. Finally, diluvial action, as I have attempted to show, did not take place till this continent had attained nearly its present elevation above the ocean.

Nearly the same difficultics encumber another theory, which imputes diluvial action to the retiring waters of the ocean, as chains of mountains were suddenly thrown up. If the continent was already above the ocean when it took place, this would be impossible. Or if it were not, as it rose, the waters would rush each way from the central axis: but in fact they moved only in a southerly direction. Again, the direction of the current was not at right angles to any system of elevation in this country with which we are acquainted: And finally, the effects vastly transcend the alledged cause.

The only remaining theory deserving notice, supposes that an extensive elevation of the bottom of the Arctic Ocean threw its waters, loaded with ice and detritus, southerly over the American and also the Eastern Continent. It supposes that theremay have been a succession of elevatory movements, producing successive waves, so that the waters may have risen and fallen, and during their ebb, they may have frozen to the surface; so that upon rising again new loads of detritus may have been lifted up, and driven onwards, and even up somewhat steep declivities, scouring and abrading the surface.

This theory certainly quadrates better than any other with the diluvial phenomena of this country. Still it is very difficult to conceive how an oceanic current, however violent at its commencement, should have sufficient force, after passing southerly from the arctic region to the 45th, or even the 40th, degree of north latitude, to accomplish what the diluvial current has accomplished in this country. And at the longest, such an upheaving of the arctic ocean as is here supposed, judging from analogous movements in modern times, could not have occupied more than two or three years. But one cannot become familiar with diluvial phenomena without feeling a conviction that a much longer period must have been occupied in this work; although compared with many other geological periods it was short.

To my mind, therefore, no theory of diluvial action hitherto proposed, is so free from objections that I feel satisfied with it. That remarkable and very powerful currents of water have swept over this continent from the north and northwest, I cannot doubt. That this took place at a compara-

tively recent period, and probably since the continent assumed its present levels, and reached essentially its present height above the ocean, and that no existing agency, without a great increase of intensity, could have accomplished the work, seem to me almost equally certain. But I do not feel prepared to propose any regular theory of this agency in which I place much confidence. Yet the subject is one of the deepest interest, and the facts are fast accumulating concerning it; so that erelong I doubt not every theoretical difficulty will vanish.

### *Concretions in Diluvial Clay.*

In the clay beds of New England, which I have described as diluvial, two distinct and peculiar varieties of concretion occur, which deserve a particular description. One of them is composed of carbonate of lime and clay, and the other of hydrate of iron and clay. Though familiar with the former from my earliest days, under the name of ***claystones***, as is every boy brought up on the banks of Connecticut river, yet it is only since my last report to the Government that my attention has been particularly turned to the subject. They are, indeed, described briefly in my Report of 1835: as are also the other variety produced by the hydrate of iron; the latter I then regarded as organic remains. This opinion, upon the whole, I think must be given up: though the resemblance to organic remains is strong. The claystones are almost universally referred by the community to the action of water upon indurated clay. And since they are always rounded and generally found in the beds of streams, this is a very natural, though an entirely erroneous conclusion. They are undoubtedly concretions, formed by laws somewhat analogous to those of crystalization; probably while the clay was in a soft state, by the action of water.

I freely confess, however, that so far as my means of information extend, the subject of concretions is involved in great obscurity. That they are formed by segregation, in consequence of elective affinity, seems to be generally admitted. But why the particles should arrange themselves in curves, rather than in straight laminæ, it seems difficult to determine: and we are quite ignorant whether any of the laws of crystalography will apply to the formation of concretions. Prof. Alexander Brongniart has, indeed, given the world a valuable paper on siliceous concretions. (*Annales des Sciences Naturelles, Tome Vingt—Troisieme, p.* 166.) And he has rendered it probable that silica takes the form of a concretion when in a gelatinous state, and of a crystal, when in a state of solution. But this gives us not even a glimpse of the laws that regulate the arrangement of the particles: nor explains the reason why they should assume one form when in a gelatinous condition, and another

when in a state of solution. Nor will the case which he has described afford much assistance as to the concretions under consideration; first, because in these the silica could not have been in a gelatinous state when they were formed; and secondly, because the particles in the most important variety, the claystones, are not arranged in concentric coats, as they are in most siliceous and in many calcareous and ferruginous concretions. H. T. De la Beche, in his Theoretical Geology, (*Chap. V.*) does, indeed, describe silico-calcareous concretions in the mechanical rocks of England, very similar to our claystones: and he has satisfactorily shown how the particles might have been aggregated together by affinity: but not why the mass has a rounded instead of a polyhedral form. The siliceous limestone of Fontainbleau contains more sand than the claystones of Massachusetts: and yet its crystalline form is preserved. Why is it not preserved in the these claystones? Dr. Fitton, in his able "Observations on the strata between the Chalk and Oxford Oolite in the south east of England," has made the important suggestion on the subject of concretions, that they may depend partly upon electrical agencies for their production: (p. 121.) But perhaps theoretical considerations should be deferred till I have described the concretions of Massachusetts. I indulge a feeble hope, that such a description will throw a gleam of light upon this difficult subject: not enough, indeed, to disclose the laws of concretionary structure; but enough to prove more clearly than has been done, that there are such laws, as definite and fixed, probably, as in crystalization: and that by further research they may be discovered.*

## *Claystones.*

I shall first mention the localities and situation of the claystones of Massachusetts.

They are more abundant in the valley of Connecticut river, than in any other part of the state. In general they are found beneath the waters of the river, where the bank consists of fine blue

*Although the statements given in the text show us that concretions similar to our claystones are not unfrequent in Europe, yet some facts, that have recently come to my knowledge, have led me to doubt whether their nature is not even yet misunderstood by some of the learned naturalists of that quarter of the globe. Among specimens recently received from an able English geologist, was one from the Kimmeridge Clay, a little larger than the Spanish dollar, and of the same shape, which differs from specimens of claystones in Massachusetts only in containing less of calcareous, and more of carbonaceous matter, but not in its artificial appearance, which to be sure is striking. This specimen was thus labeled: "Kimmeridge Coal Money, (use and age unknown,) found abundantly in the Kimmeridge Clay, Dorset Coast.—Supposed turned in a lathe and anciently used as money." Still more recently I have received from a distinguished Prussian mineralogist, Mr. Frederick Tamnau Jr. of Berlin, not less than 20 specimens of concretions, from Nykoping in Sweden; which are precisely like the claystones of Massachusetts. They are denominated in Sweden *Malryaka;* and Mr. Tamnau adds; "the Swedish scientific men believe them to be something of organic remains:—some sort of mollusca, which were more or less wrapped in a mantle. I am not of the same opinion. I believe them calcareous concretions, like those you sent me. It is remarkable that they are found in a little bed of clay in the midst of primitive rocks." The specimens which I sent, alluded to above, were claystones from Massachusetts and Connecticut.

diluvial clay, in horizontal layers, about half an inch thick. Sometimes the water has removed them several rods; but rarely far enough to wear them much. The most abundant locality, is in Hadley, on the east side of Connecticut river, half a mile south of the village. In South Hadley (or perhaps within the limits of Springfield,) they occur half a mile south of the village, at the Canal, in a clay bank by the road side, some 50 feet above the river. In West Springfield they are found at the mouth of Agawam river; and also a mile up the stream, near the bridge leading to Suffield. In Amherst they are washed from a bed of clay at some distance from any stream. In Deerfield, they occur on the bank of Connecticut river, a few rods north of Sunderland Bridge. In Montague, they are seen at low water on the east bank of Connecticut river, in a clay bed, which underlies a meadow. Specimens will be found also in the State collection from Windsor and Wethersfield in Connecticut: where they are common in the clay beds, and differ from those in Massachusetts only in having the reddish tinge which is there common in the clay. Although I have seen imperfect claystones from the vicinity of Boston, and have heard of them in other parts of the State, yet I have met with good specimens out of the valley of the Connecticut, only in North Adams, where they are common in a clay bed which has been excavated for making brick. Along Hudson river they are quite common: and I have met with them at the slide on Presumpscut river near Portland in Maine. Indeed, they are found in nearly every part of our country, where diluvial clay exists.

At most of the localities in Massachusetts that have here been described, thousands of specimens can be obtained.

### *Chemical Composition.*

The following analyses of these bodies, although not carried as far as they might have been, will afford probably nearly all the requisite information as to their composition, except perhaps in one or two respects.

| | West Springfield, Mouth of Agawam River. | West Springfield, 1 mile further West. | Hadley. | Deerfield. | Adams. |
|---|---|---|---|---|---|
| Carbonate of Lime, | 48.4 | 42.1 | 56.6 | 49.9 | 53.6 |
| Carbonate of Magnesia, | | 3.3 | | 3.8 | 1.2 |
| Silica, Alumina, Iron, &c. | 51.6 | 49.6 | 43 4 | 43.4 | 45 2 |
| Iron, and Organic Matter, | No trial. | | No trial. | 0.4 | No trial. |
| Iron, Phosph. of lime, and Org Mat. | Do. | 1.6 | Do. | | Do. |
| Water. | Do. | 3.4 | Do. | 2.5 | Do. |
| | 100. | 100. | 100. | 100. | 100. |
| Specific Gravity, | 2.68 | | | | 2 60 |

The two following specimens were obtained from Nykoping in Sweden, as described in a note on page 407.

| | 1st Specimen. | 2d Specimen. |
|---|---|---|
| Carbonate of Lime, | 60.33 | 61.26 |
| Carbonate of Magnesia, | trace. | 1.40 |
| Silica, Alumina, Iron, &c. | 35.20 | 32.20 |
| Iron, Organic Matter, &c. | 1.80 | 1.70 |
| Water. | 2.67 | 3.44 |
| | 100. | 100. |

The process which leads me to suppose the presence of organic matter, was the following: The solution of the claystone in nitric acid, being evaporated to dryness, and hot water added, a dark coloured mass remained undissolved: which, on drying, took fire and burnt like powdered charcoal: although thorough ignition could not reduce the mass in weight more than one fifth. I cannot conceive what else besides carbonaceous matter, could have conducted in this manner. And yet the claystone in powder, thoroughly ignited, did not turn black at all, or show any tendency to inflammation. Hence, if carbon existed in it, it must have been in such a state of combination, that the decomposing power of acid was necessary to bring it to light. Upon the whole, I infer the presence of a small quantity of organic matter in these claystones; although in the specimen analyzed from Deerfield, it was scarcely perceptible. In that from West Springfield, it was much more obvious.

It may be, that this fact was one of the reasons that has led scientific men in Sweden, (as mentioned in a note on p. 407,) to regard claystones as petrifactions. The fact does certainly favor that opinion. On the other hand, the facts which I have to mention respecting their forms, render it almost certain that they must be concretions. That a solid animal once occupied the place of the claystone, that is, an animal with a skeleton, or a shell, cannot be maintained; because every vestige of such solid parts has disappeared. And even if we admit that the remains of some soft or gelatinous animal did form the nucleus of the claystone; yet the particles appear to have been brought together by molecular attraction: and did not assume the form of the animal but that of concretions. It may be that organic matter was necessary to determine the concreting particles to particular centers. But I regret that I must leave this part of the subject with only a glimpse of light, as it was only by stopping the press, (Nov. 1840,) that I have been able to make the few analytical trials that have been detailed.

Another important inquiry is, whether these claystones form a definite compound of carbonate of lime and clay. The preceding results will hardly justify us in maintaining the affirmative. I incline to the opinion, that they consist simply of a portion of that clay in which they are enveloped, that is cemented by infiltrated carbonate of lime and magnesia. The particles of clay do not appear to have changed their place at all: And of course, the quantity of lime and magnesia introduced, would depend upon the quantity and state of the menstruum, and of the lime and magnesia. If this be a correct view, the claystones are analogous in their mode of formation to mortars. But as certain proportions of the ingredients form the hardest and most perfect mortars, so probably it is in the claystones: and I doubt not but extensive analyses might discover these proportions.

## *Physical Characters.*

The hardness of these concretions when freshly broken, is little less than that of common argillaceous limestone. On their exposed surfaces they are usually softer, either from partial disintegration, or from an excess of clay. When broken, the concretion appears compact and perfectly homogeneous throughout. In no case have I discovered a concentric, or oolitic structure: nor did the application of strong heat develope it; although such heat usually splits the mass asunder into irregular fragments. In some cases, especially where the concretions are considerably thick, the surface, after long exposure to atmospheric and aqueous agencies, shows

a laminar arrangement of the particles, corresponding to the laminæ of the clay in which they are imbedded : but they will not divide in that direction with much more facility than in any other. In a very few cases I have met with a pebble, or a congeries of coarse sand, near the center of the claystone, which appeared to have been the nucleus around which the particles collected : but in ninety-nine cases out of a hundred, no such nucleus can be discovered : although it is undoubtedly true, that there must have been something to determine the particles to a particular center. In no case in Massachusetts have I seen any organic relic at the center, nor indeed any where in the clay beds. But in Maine, small shells do sometimes occur in the concretion : yet they did not appear to me to form a nucleus, but to be rather accidentally enveloped by the aggregation of the matter around them. In like manner, I have sometimes met with large pebbles, partly coated over with a claystone : but not properly constituting the nucleus.

But though on breaking these concretions no marks of a laminar arrangement appear, yet the surface, in a majority of instances, shows that the accretion took place by successive deposits. This is particularly obvious in the flat varieties ; where the matter was added by successive rings ; some of which are fuller than others. An inspection of Plates 15, 16, and 17, will furnish abundant examples. Yet if any of the specimens there figured were broken through, no appearance of separation could be found between the successive layers of matter.

As to color, these concretions almost always take that of the clay in which they are found : and this is usually a light gray, or reddish. In a few instances different parts of the same concretion have different colors, because somewhat different in composition : and in such cases the two kinds of matter appear to have been under the influence of two centers of attraction and the concretions are less firmly united to each other than where no difference exists in the matter.

In general the concretions have a thickness less than a single distinct layer of the clay : which rarely exceeds half an inch. Sometimes the layers are a good deal thicker : and sometimes, also, I apprehend that the concretion may have extended into more than a single layer. The horizontal extent of the concretion is often quite large, while its vertical range is very small : and I have no doubt but this fact has had great influence in modifying the forms which the claystones have assumed. It will give a good idea of the manner in which they are arranged in the clay, and probably too, an accurate notion of the manner in which they were formed, to suppose the matter of which they are composed to have been originally disseminated equally through a thin stratum of clay, and to have been subsequently aggregated around different centers of influence.

### *Form.*

We now come to a part of this subject the most interesting and yet most difficult. When examining the forms of these concretions from different localities, I have often felt as if I could almost reach the great principle of their formation. I feel as if I stood on the brink of interesting discoveries ; and often regret that I must bring out my descriptions in so crude a state ; when perhaps longer reflection, and specimens from a wider range, might unravel all the mystery. As it is, all I can hope to do, is to render it probable that these concretions are formed by laws as certain as those which regulate crystalization : and that in fact, there is a strong analogy between the two processes.

One cannot examine these concretions from different localities, without perceiving that they affect certain forms; which may be called the predominant forms. We find, it is true, numerous intermediate forms: But then, in the midst of all the variety, the tendency to these predominant forms is obvious; and there would seem often to have been a struggle among them for the mastery: so that not unfrequently we perceive in the same concretion, at least two distinct forms, somewhat modified by mutual influence. I shall not attempt to state how many of these predominant forms exist in nature. But in the specimens that have fallen under my notice, I think I can recognize the six following: though nearly all of them might be regarded as modifications of the first.

1. The Sphere.
2. Oblate Spheroid.
3. Prolate Spheroid.
4. Annulated.
5. Lenticular.
6. Cylindrical.

1. *The Sphere.* This is the form which we should suppose the particles of matter would assume, when suffered to concrete around a center of influence, with nothing to disturb their free movement towards that center. But as we have reason to suppose that only a thin stratum of clay would at any one time be in a state sufficiently fluid to allow of such a movement, either the spheres would be small, or other forms, would result. We accordingly find that the perfect sphere is one of the most unusual of the forms above named: and I have rarely seen it more than half an inch in diameter. More usually the specimens are not larger than small shot, and often as small as the head of a pin. Frequently the surface of a flat claystone is thickly studded with these small spheres, so that they run into one another; and sometimes they shoot out in irregular masses from the surface, so as to become botryoidal. The best locality of this variety of form is in South Hadley, a little south of the Canal Village. Plate 16, Fig. 25, is an example. At the slide on Presumpscut river, near Portland, in Maine, I have noticed the large detached spheres.

2. *Oblate Spheroid.* In all our reasoning concerning the formation of concretions in clay, which is a mechanical deposit, we ought to suppose the particles to be only in a plastic, not in a fluid state; and although the carbonate of lime was probably in a state of solution, yet the particles of sand would obstruct the movement of the fluid towards particular centers; and therefore, counteract the natural tendency of the limestone to assume a certain form. Suppose then a perfect sphere begins to form in a thin layer of clay. Here the matter to be concreted has a great horizontal, but a small vertical extent. Consequently, the accretions in a horizontal direction will be more rapid than in a vertical direction; both because the matter is more abundant in the former than in the latter, and because it meets with greater obstruction in passing to the latter. The result will be an oblate spheroid, whose shorter axis is perpendicular to the stratum in which it is formed. In the localities which I have examined, perfect oblate spheroids are unusual. I have seen them at the mouth of Agawam river, at Hadley, and at Deerfield. In many cases one half of the spheroid is exhibited, while the other half is almost flattened into a plane: a circumstance that may be explained, by supposing the lower part of the stratum of clay to be in a state more favorable to the accretion of the particles of carbonate of lime than the upper

part; so as to cause the most rapid accumulation around the lower part of the axis. This form frequently passes to the state of a cone: And I think it not difficult to see how by some slight modifying causes, such singular forms as are shown on Plate 16, Figs. 18 and 19, were produced. The case just described explains Fig. 18, except the abrupt temination of its top; which may have resulted from its close approximation to a stratum which did not admit of the free transmission of the cementing carbonate of lime. The projection of the top of Fig. 19, might have been produced by the extension of the concreting process into a layer of clay more favorable to the accretion of the particles, than that layer in which the part of the claystone smallest in diameter was formed.

3. *Prolate Spheroid.* Supposing the conditions of the medium in which the concretions were formed to be the same as in the last case, we can conceive of a modification of circumstances, by which the horizontal axis of the sphere might be lengthened, so as to form the prolate spheroid. To produce the oblate spheroid, we must suppose the stratum of clay equally pervious to the cementing particles on all sides in a horizontal direction. But suppose the clay to be pervious only along a space which has the form of a cylinder. The consequence must be an elongation of the axis of the sphere which coincides with the axis of the cylinder, and the consequent production of a prolate spheroid.

Exactly such a state of the medium as to produce a perfect prolate spheroid, we must suppose to be extremely rare; and hence such a concretion is extremely uncommon. Still, one of the most usual forms of the claystone, appears to me to be the combined result of the conditions by which the oblate and prolate spheroids would be produced. If the concretion should enlarge so that the horizontal diameter becomes longer than the vertical—that is, longer than the thickness of the layer of clay in a fit state for producing it—the sphere would become oblate. But if when thus enlarging it should extend most rapidly in two opposite directions, the prolate character would be imparted to it: or if it should enlarge unequally in different horizontal directions, its character would still be prolate-spheroidal; while at the same, time its narrow vertical limits of increase would continue its oblate character; and thus might be produced a flattened ovoid, which is a common form of these concretions: or there might be several flattened ovoid projections, which is a still more common form. In this way I conceive the principal body of the concretions exhibited on Plate 16, Figs. 20, 33, 34, and Plate 17 Fig. 35, 38, 41, 43, 44, 47, 48, 45, 46, 51, 52, 49, 50, 53, may have been produced: although in some of these cases, there is another principle, which I shall subsequently describe, that may explain some of their irregularities. The localities where these forms predominate, are Windsor in Connecticut, Deerfield, Montague, and Adams, in Massachusetts.

4. *Annulated.* Let us imagine the spherical nucleus of the concretion to have so narrow vertical limits, that, as it enlarges, it takes the form of a circular plate Suppose farther, that the additions are made in the form of rings, of different width and thickness; so that the successive accretions are obvious to the senses. We shall then have an idea of what I have denominated the *annulated form* of these concretions. The locality in Hadley furnishes specimens of this form in great abundance; and, indeed, few other forms are found there. Plate 15, Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and Plate 16, Figs. 16, 17, 26, 27, are some of the most remarkable varieties from this locality. And probably this is the most instructive class of these singular bodies: and yet there are more things about the varieties of the annulated form, which I find difficult to explain, than in respect to any other.

The increase of these concretions by successive broad rings, is one or these difficulties. In the specimens from Hadley, which are more perfect than I have anywhere else seen, the center is usually slightly the thickest part; (the thickness rarely exceeds a quarter of an inch,) and then, by a slight curvature of the surface, the thickness diminishes outwards as if the matter were diminishing in quantity; which we should suppose would probably be the fact. But immediately be-

yond the thinnest part, the concretion resumes its original thickness, and a ring of considerable width forms its circumference. I can imagine no possible explanation of this occurrence, unless we suppose, that when the outer ring began to form, the clay became more pervious to the cementing matter, but from what cause I cannot conjecture: or that a new supply of carbonate of lime was introduced. In the specimens at Hadley, it is not usual for more than one or two distinct rings to be formed around the central plate. But in some specimens from Adams, shown in Plate 17, Figs. 36, 37, several imperfect concentric bands exist.

The extreme regularity of the specimens from Hadley, is surprising. They could scarcely be turned out more accurately by a lathe; and their surfaces are as smooth often, as if such were their origin. It is no wonder that they should be so often regarded as artificial. The specimen, Plate 15, Fig. 1, is five inches and a quarter across; and the outer ring an inch across. This is the largest regular concretion of this sort which I have ever seen. It is only about one tenth of an inch thick.*

The modifications of the annulated form are numerous and remarkable. The simplest change is a deficiency of a few degrees in the outer ring: the two extremities of the remaining portion being always gracefully curved. Sometimes, though perhaps not always, this curve is epicycloidal. In general, the entire outer ring disappears at the part deficient, while the remaining part remains unaffected. I have never seen a smaller portion of the outer ring wanting than is shown on Plate 15, Fig. 3, where the deficiency is about 30°. This is less common than Fig. 4, which has a deficiency of 110°. Fig. 5 shows a deficiency of about 180°: And Fig. 8 of 300°. Several others which I measured gave 35°, 40°, 45° 50°, 60°, 70°, 80°, 115°, 140°, 160°. Such measurements cannot of course be very accurate; as an inspection of the drawings will show: because the curved extremities of the deficient ring meet the circumference of the inner ring at so acute an angle. I had almost persuaded myself that the deficiency in the outer circle would be found to increase from the minimum to the maximum by a fixed quantity. But the above measurements do not sustain such an opinion. I think, however, that the deficiency of 70° or 80° is much the most common.

The above statements apply only to the most perfect specimens: and as there are defects in crystals, where some of the conditions for their perfect formation were wanting, so we find specimens of these concretions with an irregular circumference, apparently from a deficiency of materials, or subsequent disintegration The second ring, also, is sometimes partly deficient. But cases of this sort are so few as to form only the exception to a general law that prevailed in their production.

The next variety of modification consists in a deficiency of the outer ring on opposite sides of the plate, as is shown in Plate 15, Fig. 6. In such a case, the bounding curves of the rings sometimes lose more or less of their circular form; as the above figure shows in a slight degree; and it is seen much more strikingly on Plate 17, Fig. 37, which represents a specimen from Adams, where only a few of the annulated claystones occur; and these somewhat anomalous in their characters. The deficiency of the outer ring becomes in some specimens so great that only two portions of it, like ears, remain; as shown on Plate 15, Fig. 7. In some instances three of these projections remain, as in Fig. 9.

When these projections are on opposite sides of the plate, as in Fig. 10, Plate 15, we have, it seems to me, the commencement of another modification of the annulated form. The projections constitute new centers of attraction; and by the process of accretion around the three centers which now exist, we have produced the form represented on Plate 15, Fig. 11; and on Plate 17, Fig. 43, which was found in Deerfield. It is difficult to explain all the cases of this kind, without

* This specimen is reduced in diameter more than one half in the drawing: and all the other figures are reduced in the same proportion from the natural size.

supposing that the new centers of attraction have the power of abstracting the particles of the cenral plate after it is formed. In Fig. 12, Plate 17, the extreme plates seem to have predominated over the central one, so as to destroy almost its circular form. The process has gone still farther in Fig. 13, where the extreme plates are connected only by a thin and narrow strip of concretion. In Fig. 14, one of these concretions seems to have greatly predominated over the other, resulting perhaps from the more favorable state of the medium in which they were formed, at one extremity than at the other; or from a deficiency of matter at one end. In like manner, we may explain Fig. 15, Plate 15, from Hadley; and Figs. 16 and 17, Plate 16, from Deerfield, where three centers of attraction appear to have existed besides the original one; which, according to the supposition I have made, have abstracted more or less of the original plate. It is not necessary, however, to suppose the original plate to have had a circular form. It may have had an irregular outline. And yet, there is too much regularity in the relative position of these centers on the above figures, to be explained without supposing it fixed by some law.

Plate 16, Fig. 27, is a case in which one of the extremities, or plates, assumes an oval shape from some slightly modifying cause in its formation. The projection upon one side, appears due to a similar cause. In a few cases I have found specimens like Fig. 26, Plate 16, with the central nucleus wanting; perhaps because it might have been a pebble It is also an example of a deficiency in opposite parts of a broad outer ring, one of which deficiencies is bounded by a chord to the inner circle. The vacant nucleus is considerably out of the center; although this is scarcely shown in the figure: but I apprehend that to have been the center of attraction.

In a few instances I have seen the annulated form embracing the spheroidal; as Plate 17, Fig. 54. This produces a singular yet elegant claystone.

5. *Lenticular*. Perhaps I ought to have considered this as a variety of the annulated form. For the central plate in the latter, is often lenticular; and if the outer ring were wanting, it would be a perfect example of this form. It is cheifly the sharp edge of the circumference that distinguishes this form from the annulated. At the Hadley locality the lenses are sometimes several inches across, and the edge extremely thin. At the Amherst locality, where this form is the predominant one, the concretions are much smaller and thicker, and the convexity is often much greater on the upper than the under side. Figs. 21, 22, 23, and 24, were sketched from that locality. The concretions there are often aggregated together, as the drawings show: and this is almost the only variety of this form that I have found. What circumstance could have given the sharp edge to this form, I find it difficult to conceive. Perhaps, however, the stratum in which they were formed, was at first easily pervious to the cementing material, but gradually became too hard to permit its passage on its upper and under sides, and thus narrowed the surface of accretion, until the whole stratum became at length impervious.

6. *Cylindrical*. We have only to suppose the process already described, by which the prolate spheroid might have been formed, to continue long enough, and a cylinder will be the result, with rounded extremities; which are always present. Plate 16, Fig. 28, shows a specimen from Hadley, which approaches the perfect cylinder as nearly as I have usually seen, although the different parts vary a good deal in diameter. If the stratum of clay is too thin to allow the formation of a perfect cylinder, then a flattened one would be produced, by the same principles as have been stated in respect to the oblate spheroid. And this in fact is the most common variety of the cylindrical form. Plate 17, Fig. 55, is an example of this variety, from West Springfield, in the banks of Agawam river, near where the bridge from that place to Suffield crosses it. It is almost the only variety found there. At other localities I have scarcely met with it. It seems to admit of very little variety, except that it is not always straight, nor of equal width.

*Compound Forms*. Not a few examples occur in which at least two of the preceding simple forms are found in the same concretion. In Plate 16, Figs. 30, 31, 32, 33, and 34, and Plate 17,

Figs. 35, 38, and 39, from Adams, we perceive the nuclei of several spheres, partly imbedded in the flattened irregular prolate spheroid. It would seem as if the concretions began with the spheres; but from some cause the medium soon became unfavorable for their increase, while an adjoining layer, either above or below, became favorable to the formation of the flattened irregular prolate spheroids; and the concreting matter partially enveloped the spheres, but could not entirely surround them, for the reason above given. On Plate 16, Fig. 42, from Deerfield, we have a simple ring surrounding one of the poles of an oblate spheroid. On Figs. 40 and 41, from Windsor in Connecticut, we have the prolate spheroidal form associated with the flattened cylindrical. In Fig. 40, the latter does not pass directly through the former; but it does in Fig. 41. And in such a case, we must suppose the cylindrical form to have been first produced, and then, by some change in the condition of the clayey medium, or the solution, a prolate spheroidal figure was accumulated upon it. Figs. 46, 47, and 51, from Deerfield, are of the same character as those just described. In a few instances I think I can discover three distinct simple forms in the same concretion; but they are not very distinct.

I have now described the most important varieties of claystones that have fallen under my notice. I possess, indeed, many others which differ slightly from those exhibited upon the drawings. But I did not feel justified in multiplying the drawings beyond the present number. In attempting to show how the different predominant forms and their varieties may have been produced, by supposing the clay in a plastic state, and pervious to the concreting solution, I have given all of theory that I feel able to do. On the more difficult question, why the concretions assume a curved rather than a polyhedral form, I have nothing to offer. That it depends upon the imperfect mobility of the particles of the clay, so that resistance is offered to the cementing material, seems highly probable: but this is simply a fact, not its rationale.

There is one fact which may be learnt from the preceding descriptions; but which is so important as to deserve a formal statement. It is well known that peculiar varieties of form in crystals of the same mineral, characterize, or rather predominate, at different localities; occasioned doubtless by peculiar modifying causes in their formation. The same is true of these claystones. Thus, at Hadley, the annulated form most decidedly predominates; as does the lenticular at Amherst, the cylindrical flattened at one of the localities in West Springfield; and various compound forms at Windsor in Connecticut, at Adams, Deerfield, and Montague, in Massachusetts. In the four last named localities, there is also some slight peculiarity of the compound form, easily recognized, but not easily described; as may be seen upon the drawings.

This fact presents us with another very striking analogy between concretion and crystalization: and added to all the other analogies that have been described, renders it highly probable that the former as well as the latter is

the result of unalterable laws, and therefore we may hope the day is not distant when both will be equally well understood.

In conclusion, let us review the ground over which we have passed.

In the first place, a short review of our knowledge concerning concretions in general, shows us that the subject is yet very imperfectly understood; and that in respect to the peculiar silico-calcareous concretions that are found in clay, we seem yet exceedingly in the dark.

In the second place, the claystones of New England, found in diluvial clay, appear to be composed of clay cemented by carbonate of lime; and hence the proportion of this latter ingredient will vary according to the nature of the clay.

Hence, thirdly, we may presume that these concretions were formed by the accretion of the carbonate of lime around certain centers of attraction in the clay; which, although pervious to the solution of cementing matter, does not appear to have been removed from its original position.

In the fourth place, we find in Massachusetts as many as six fundamental or predominant forms, which the concretions have assumed: viz. the sphere, the oblate spheroid, the prolate spheroid, the annulated, the lenticular, and the cylindrical, with numerous varieties of these forms; and sometimes at least two of them are combined.

In the fifth place, if we suppose the conditions as stated under the third particular, and conceive of modifications in the form and consistency of the clay, and the carbonate of lime in solution, we can give a probable explanation of the mode in which all the varieties of form found in Massachusetts were produced.

In the sixth place, as in crystals, so in these concretions, peculiarities of form characterize different localities.

Finally, the conclusion is forced upon the mind, that these concretions are produced by laws as definite as those of crystalography.

I will only add, that to show how numerous centers of attraction could exist, often close to one another, and perhaps also, to explain some other phenomena, it seems to me we must call in the aid of Galvanism.

### *Imitative Forms of Claystones.*

Although not connected with their scientific history, I can hardly pass in silence, what must strike every one who looks at the drawings which I have given of the claystones, and especially every one who looks at the originals. I refer to the resemblance that often exists between them and certain animals or productions of human art. One cannot but see for instance, in Plate. 16, Figs. 29, 30, 31, 32, 33, 34, and Plate. 17, Figs. 35, and 39, a striking resemblence to a collection of Chinese or Hindoo gods, as represented by images and drawings. Fig. 27, Plate 16, and 47, 48, 52 and 53, Plate 17, remind us of birds: Figs 41, 51, and 46, Plate 17, of quadrupeds;

Fig. 50, Plate 17, of the seal: Fig. 1, Plate 15, of a wooden trencher: Fig. 13, Plate 15, and fig. 17, Plate 16, of spectacles: Fig. 19, Plate. 16, of the top of a tea pot, or sugar bowl, and Fig. 18, same Plate, of a broad brimmed Chinese hat; and Fig. 54, Plate 17, of the extremity of various posts, turned in a lathe. And yet these resemblances are so clumsily executed, that they seem to be mere mimicry: or to apply what Shakspeare says of certain stage players," it seems as if Nature's journeymen had made men and not made them well, they imitate humanity so abominably."

A very curious collection of these burlesque imitations might be made out by visiting various localities of claystones.

Numerous claystones, extending from No 1592 to 1682, will be found in the State Collection.

## *Ferruginous Concretions.*

These are less distinct and far more fragile than the claystones. Although they do sometimes occur in the pure clay, I have more frequently found them near the upper part of the bed, where the clay takes an increased amount of sand into its composition. Sometimes they occur in the fine sand, or loam, above the clay, and even in alluvial deposits.

I have found the most perfect of these concretions in the valley of Connecticut river. In Deerfield are four localities: one at the earthen base of North Sugar Loaf in clay: one on the banks of Deerfield river, a little northwest of the village in alluvium: another, on the same river, in the north part of the meadows in alluvium: a fourth, and the most remarkable, a little south of the village called Wapping, in the clay cliffs through which the road is cut in ascending Long Hill. They occur also in clay at South Hadley canal. On the banks of the Housatonic, in Sheffield, in a locality in alluvium. I have noticed them in the eastern part of the State, in Charlestown and Manchester; and on Nantucket, in clay.

### *Description.*

As a general fact, these concretions are made up of concentric alternating layers of clay or loam, and the same material more or less coloured or consolidated by the hydrate of iron: so that when one extremity has been exposed for some time to the weather, the softer layers, that is the clay or loam, wear away and leave the intervening harder parts projecting, in the form of cylinders set within one another. The inner ferruginous coats are usually the thickest and most solid; and, indeed, the outer ones, although having the tinge of hydrate of iron, have scarcely more coherence than the unaltered clay or loam. Hence when specimens sufficiently consolidated to hold together are dug out, they are usually much smaller than the original, though of the same form essentially. Hence the sketches on Plate 18, Figs. 1, 2, 3, 4, 5, 6, 7, 8, and 9, with the exception of Fig. 6, are only the nuclei of the concretion: yet, as they probably give a good idea of their shape, this is of small importance.

These concretions assume at least three distinct forms; viz. the sphere, which is often oblate; the conoid, and the cylinder: and frequently these forms are all united in the same specimens, as may be seen upon the drawings above refered to. Sometimes the cylinders are very irregular, as if formed around small branches of vegetables. ( See Nos. 1586, 1587. ) No 1588 has a good

deal the appearance of a fossil bone; and as it was found in alluvial soil, only a few feet below the surface, on an old battle field between the Indians and the Americans, I am by no means certain that the nucleus was not a bone.

As a general fact, the upper part of the concretion is terminated by the segment of a sphere: as may be seen in Figs. 1, and 2. Most commonly the cylindrical stem forms the termination beneath. Their most usual position is perpendicular to the layers of clay, or loam: but sometimes they incline as much as 45°; and sometimes lie horizontal. This is especially the case in alluvium. In height I have rarely seen them more than six inches; and in diameter, rarely more than four, but sometimes they are several feet long. The axis of the concretion is always occupied by a tube; the diameter of which is rarely more than the twentieth of an inch; commonly much less. I have sometimes seen this occupied by the root of a species of equisetum: as on the banks of the Housatonic, in Sheffield. In some cases, however, the great depth beneath the present surface where they are found, precludes the idea that the root of one of these plants could have reached the spot; being 15 or 20 feet, and several feet in clay; into which plants rarely send their roots. In other cases, as in some specimens already mentioned from Deerfield, the form and size of the cavity do not correspond to a small cylindrical root. Yet I can hardly doubt but in every case some organic body formed the axis; and thus became the nucleus of the concretion.

In almost all cases, the original lamination of the clay can be traced, almost without interruption, through the concretions; and even where the nucleus has become so much consolidated as to sustain a considerable blow without breaking, the layers are distinctly visible. In general, they are apt to separate when drying, in the direction of their lamination. This shows us that it is chiefly the iron that has been moved in the production of the concretions; while the clay has remained nearly as deposited.

In general, these concretions are insulated in the clay and loam: But sometimes they are in clusters; so that the concentric coats interfere with one another. Professor Emmons has given an instructive sketch of such a cluster from the clay beds of Champlain in New York, where they occur abundantly. (*Report of the New York Geologists for* 1837, *p.* 233.)

I have called these concretions ferruginous. But I have a specimen from a clay bed in the state of Maine, (near Hallowell, I believe,) in which a perfect cylinder exists, near an inch in diameter, with a perforation along its axis, containing the root of an equisetum; and yet the clay of the concretion cannot be distinguished in appearance from that which surrounds it; which is the common blue clay. Here there has not been any segregation of the hydrate of iron: all the iron being, as is usual in our blue clay, in the state of protoxide. We may, therefore, be certain, that the iron is not essential to the formation of these concretions. Probably the existence of an organic axis, and a certain state of the clay, are all that is essential.

The central part of these concretions in Manchester, is composed of white, and the outer part of yellowish clay. Hence it is not strange that they should be regarded in that place as human bones: for the resemblance is strong.

## *Jointed Structure in Diluvial Clay.*

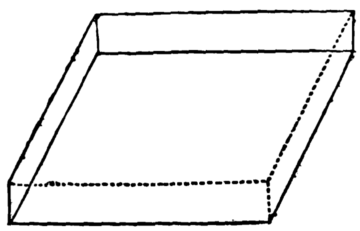
Before presenting any theoretical considerations respecting the ferruginous concretions just described, I shall give a description of a jointed structure in some of our clay beds, which appears to me to be a more simple operation of the same general cause which produced the concretions.

It is well known that nearly all the consolidated stratified rocks are often separated by divisional planes into prismatic masses, approaching the rhomboidal; sometimes into perfect rhomboids. The same joints occur in the diluvial clay of Massachusetts. I can refer to three accessible localities. One is on the south bank of Agawam river, half a mile east of the bridge on the road leading from West Springfield to Suffield, where thousands of these prisms may be seen in the clay beneath the diluvium. The layers of clay here are perfectly horizontal; as

they are in the two other localities. On the west bank of Connecticut river, a few rods below the mouth of Deerfield river, is another locality: and a third exists on the south bank of Deerfield river, in the north part of Deerfield meadows, near Pine Hill. These cannot be seen, however, except at low water. The locality at West Springfield is somewhat elevated above the water. In all the localities it is only a few layers of the clay that are thus divided by transverse planes, while these are underlaid and overlaid by other laminæ perfectly undivided.

The form into which these masses are almost always divided, is that of the doubly oblique prism: that is, the faces are all oblique angled parallelograms, and only the opposite planes alike. I have seen some of the faces almost rhombs; but have never seen a perfect rhomboid. Fig 84 is an outline of one of these prisms from West Springfield.

Fig. 84.



Usually the prisms are much more elongated in one direction than the specimen shown above: that is, the divisional planes are much nearer to each other in one direction than in the other. I have measured a few specimens, in order to see whether there is any approach to identity in their forms. The first column below gives the smallest angle of the oblique angled parallelogram, forming the terminal plane: the second column, the smallest solid angle formed on the longest edge of the terminal plane, by that plane and the adjacent face: and the third column, a similar angle formed on the shortest edge of the terminal plane. In all cases the opposite angles to those given, is equal to their supplement.

| | | | |
|---|---|---|---|
| West Springfield, | 64° | 80° | 73° |
| do | 67 | 80 | 74 |
| do. | 76 | 81 | 81 |
| do. | 81 | 81 | 83 |
| do. | 84 | 86 | 82 |
| do. | 85 | 87 | 84 |
| do. | 87 | 88 | 85 |
| Deerfield, | 60 | 70 | 80 |
| do. | 65 | 80 | 83 |
| do. | 71 | 76 | 80 |
| do. | 80 | 84 | 88 |
| do. | 89 | 82 | 88 |

There is too much discrepancy in the preceding results to permit us to refer these prisms to the strict laws of crystalography: yet there seems to have been an effort in their formation to follow those laws: and perhaps the want of fluidity in the clay was the hindrance to their perfect conformity to those laws. If so, we may never be able to calculate the precise amount of modification which will be produced by this cause; since it seems, according to the foregoing measurements, to vary in the same homogeneous mass of clay. But I would still hope that the clue may at last be discovered, that will make the determination of their forms as sure as that of crystals.

*Theoretical Considerations.*

I have already remarked that the ferruginous concretions, which have been described, were once supposed by myself to be organic remains. Such was the opinion of others. Some, however, have always been of a contrary opinion. Professor Emmons, for instance, in his Report for 1837, is decided in favor of their being concretions. I forwarded sometime since, a few specimens to Professor Bronn of the University of Heidelberg, in Germany, distinguished for his knowledge of organic remains; requesting his views of their nature. He has favored me with his opinion, not only of their nature, but of the mode in which they might have been formed, in the following extract.

"They are surely merely concretions; formed probably by the mutual influence of the vital activity of little roots, and of the chemical disposition of the earth contiguous to them. The latter became bound in irregularly concentric layers, either because the roots deprived earthy matter of the component which had till then served to it, or to a part of it, like a menstruum; or because some product of the roots passed into the composition of the earth. By accidents of the first kind, in a class of vegetable soils, the roots of fruit trees are incrusted with carbonate of lime to such a degree as to become sick and fade away."

That the ferruginous concretions, as well as the prisms of clay, have been formed since the clay and loam were deposited mechanically, seems quite clear. For since the concentric folds of the first, usually extend through several layers of clay, with the most perfect continuity, it is not credible that the concretions began to form while yet only the lowermost layer was in existence, and before the center, or the axis, of molecular attraction existed: Nor is it more easy to see how the divisional planes of the prisms should be formed, till the layers of clay, through which they extend, were deposited. But to any one who has examined these concretions and prisms, it is not necessary to spend time to show that they are the result of some agencies subsequent to the mechanical deposition of the clay and loam.

That these agencies have acted from a center, or at least from an axis outwards, in the case of the concretions, must be equally evident. Nor can I conceive any essential difference between an agency that could cause a cylinder, an inch in diameter, to separate itself in the midst of a mass of clay, as in the specimen from Maine above described, where no chemical change appears to have occurred, and the separation of similar clay into prisms. What then, was that agency? Professor Bronn, we have seen, supposes the rootlets of living plants to have been the immediate agents in the case of the

concretions. Probably he may be correct in this supposition: for the cylindrical axis is certainly always present. But I have found it exceedingly difficult to conceive why these concretions should be so short, and terminate upwards so abruptly by the broad segment of a sphere, if the root, which must have extended far higher, was alone concerned in their production. Besides, many of these concretions are found several feet below the top of the clay bed, which must all have been deposited beneath water, and, therefore, land vegetables could not have sent their roots into it, till the whole was formed and the water drained off: if, indeed, we can suppose it possible they could ever send their roots so deep into a soil so poorly adapted to afford them nourishment. The only supposition that gives any relief to this difficulty, is to say, that the roots might have been those of aquatic plants, growing at the bottom of the waters, as the successive layers of clay were deposited.

But admitting, as perhaps we consistently may, that the rootlets of plants were the immediate agents, yet what power have they, to cause alternating layers of clay and ferruginous clay to form around them? That they might absorb mechanically the menstruum that held the iron in solution, or throw out that menstruum in the same manner, will be admitted: But a mere mechanical agency could not have separated the iron from the menstruum. There must have been some other agency to produce chemical decompositions and recompositions. And I know of no agent that could have accomplished this, under such circumstances, except Galvanic Electricity. The best vegetable physiologists now admit that the rootlets of plants form with the earths and the fluids which they contain, Galvanic circuits. Once suppose these in operation in the midst of clay beds even slightly moistened, and it seems to me we are justified, from the present state of our knowledge on this subject, in saying, that these concretions may even now be forming in clay. The recent experiments of Mr. Fox, by which a mass of clay was divided into laminæ by galvanic action, throws light on this subject; *(Phillip's Treatise on Geology, Vol. 2. p. 87.)* and shows at least, how the prisms that have been described in clay, might have been produced. Very probably, did we know a little more of the operations of this potent agency in nature, we should see equally clear how the concretions might have been formed by it. At any rate, if this will not explain them, I know not what principle will. And although I have supposed only simple molecular attraction to have been concerned in forming the claystones, I strongly suspect galvanism to have been a chief agent in concretions of every sort. It would be a curious subject of experiment to attempt to produce by galvanic action these singular bodies. He who should succeed, would doubtless be able to inform us why they are bounded by curved rather than polyhedral surfaces:

why they are sometimes composed of concentric coats and sometimes are compact throughout; and why they sometimes have a nucleus and sometimes have not. In short, with Hauy, when the fundamental idea of crystalography flashed upon his mind, he might exclaim, "*the mystery is explained.*"

The occurrence of the prisms of clay, that have been described in our diluvial clay, seems to me important in its bearing upon similar prisms in the older rocks. The latter have usually been regarded as the effect of heat. But our diluvial clay cannot surely have been subject to a temperature higher than that which prevails at present in our rivers and ponds: nor is it probable that it has ever been even sun-dried. Yet if in such circumstances prisms as perfect as in any of the older rocks have been produced, by galvanic or some other agency, why may not all have been formed in a similar manner: at least, in all those cases where the rock had a mechanical origin. Is it not more probable, however, that electricity is in all cases the ultimate agent in their production: and that whatever tends to bring the opposite electricities into more intense action, whether it be aqueous or igneous fluidity, may prove to be a proximate cause of their formation?

### *Minerals in Diluvium.*

We might expect that whatever minerals existed in the rocks exposed to the eroding action of diluvial currents, would be found in the detritus. But I shall mention only such as are interesting on account of their rareness or quantity.

I have not found gold in the diluvium of Massachusetts: but have found it in Somerset in Vermont, only 20 miles north of this state: and since the same formations that contain it there, extend southerly almost across Massachusetts, I have little doubt but it may be found here. But I have not considered it an object of importance enough to spend one half day in search of it.

A mass of native copper, weighing 17 ounces, was found several years ago in the diluvium of Whately. This was probably derived from the trap ranges of the Connecticut valley, where in Connecticut, other masses have been found. In Waltham, Dr. Samuel L. Dana discovered galena, in lamellar sulphate of baryta, in diluvial gravel. I have found galena in the same formation in Dedham, and on the bank of Agawam River in West Springfield. And I have described, in the first part of this Report, a large part of the beds of Hydrate of Iron, that are explored in Berkshire County, as having been torn from its original situation by diluvial action.

### 3. EOCENE OR OLDER TERTIARY STRATA.

A hasty examination of the strata of Martha's Vineyard, as long ago as the year 1823, led me to adopt the opinion, that the principal cliffs of that island correspond to the deposit in Europe, long known under the name of *Plastic Clay;* but now, as a part of the *Eocene Tertiary.* And I described these strata as such. (*American Journal of Science, Vol.* 7. *p.* 240.) Several subsequent examinations have confirmed me in this opinion. My chief reasons for it are as follows.

1. *The Lithological Characters of the formation.* On Plate 55, will be found a section of the cliffs of this formation at Gay Head, on Martha's Vineyard, colored according to nature. As may be seen by a reference to the description of each stratum, shortly to be given, the beds consist of white, green and yellow sands; white, gray, yellow, blue, blackish, and red clay; ferruginous conglomerate; quartzose and osseous conglomerates: and among the clays, giving them a dark color, unstratified beds of lignite. Now this corresponds almost exactly with the Plastic Clay Formation of Europe. If any one will compare the colored section of Gay Head, with one given by Mr. Webster, of the Plastic Clay of Alum Bay, in the Isle of Wight, in the Second Volume of the Transactions of the London Geological Society, he will be struck with the resemblance: as he will, if he compares the descriptions of the two spots. I did suspect that the distinct stratum of green sand, found at Gay Head, might indicate an older formation. But the organic remains which it contains, such as crabs, shells, and bones, are very much worn, and half the mass is clay; proving that this stratum consists of the ruins of older strata: ex. gr. the green sand and clay of the cretaceous formation. Similar beds occur in the Isle of Wight, and also in the Eocene Tertiary of this country; according to the Professors Rogers. (*American Journal of Science, Vol.* 38. *p.* 184.)

2. *The Organic Remains.* Although a number of organic relics occur at Gay Head, yet so far as they have been determined, none of the characteristic genera either of the middle tertiary above, or of the cretaceous group below, are among them. This is a negative but presumptive argument in favor of my opinion.

I shall now proceed to describe this formation more minutely. And since it is developed most perfectly on Martha's Vineyard, I shall first confine my description to that island; and especially to that southwestern point of it called Gay Head: an imperfect sketch of which has been already given in Fig. 30. It is a cliff of about 150 feet high, exposed to the constant action of the waves and winds.

## *Lithological Characters.*

1. *Clays.* These greatly predominate in the cliffs at Gay Head; and by the vividness of their colors, attract the attention of the most careless observer. Their variety in this respect is very great; but the following predominate. 1. *White Pipe Clay.* This obviously resulted from the decomposition of granite. 2. *Blood Red Clay.* This is doubtless colored by the red oxide of iron, and forms an important part of the cliff. 3. *Red and White Clay* mixed. 4. *Yellow Clay,* colored by iron. 5. *Bluish Gray Clay.* This is the most compact of all the varieties. It often becomes nearly black, where it lies contiguous to the beds of lignite; and when in contact with the white and red varieties, a mixture of them all results.

2. *Sands*. Next to the clays the sands are most abundant. They are there sometimes interstratified with the clays; and indeed, some varieties of the clay contain so large a proportion of sand, that it is not easy to determine whether they should be denominated clays or sands. Of the sands I have noticed the following varieties. 1. *White Siliceous Sand;* generally fine, but sometimes coarse. This is the variety which is spread over almost every part of the southeastern district of New England; generally, however, mixed with pebbles and bowlders, and constituting diluvium. It may be seen in its greatest purity near the extremity of Cape Cod, where it is of snowy whiteness: and also on Nantucket. On the Vineyard it is generally yellowish from the oxide of iron. 2. The same sand, cemented by the yellow hydrate of iron, so as to form a loose sandstone. It is easily crumbled down, however, and is not abundant. I have noticed it at Gay Head; in the cliff in the eastern part of Chilmark; and on Nantucket, a mile northwest of the town. 3. *White Micaceous Sand*. This is in fact a mixture of silex, mica, and white clay; the latter ingredient not being present in sufficient quantity to hold the particles together. 4. *Green Sand;* of a distinct but dull green color. It is sometimes so mixed with clay, as to form a compact mass, even when dry. It is interstratified with the red and white clays. It is this stratum that contains the greatest variety of the organic remains at Gay Head; and on this account, its exact geological position is important to be known. Its position may be seen upon the Section: and as I have already fully described it in the first part of my report, it is unnecessary to add more in this place.

3. *Lignite*. This exists in the form of beds, interstratified with the blue clay, chiefly. The beds rarely exceed a foot in thickness. But the lignite is so intermixed with the clay, that it is not always easy to see the dividing line. These beds of lignite appear to me to have once constituted peat bogs; and occasionally we meet with the masses of wood which such a bog would contain. So that this lignite is of two kinds: 1. A carbonaceous mass easily crumbling to pieces, and often largely mixed with clay. 2. Brittle compact lignite, showing the woody fibre. It seems to contain iron pyrites, which is undergoing decomposition; and several minute incrustations are found upon it; of whose nature I know nothing. This lignite makes but poor fuel.

4. *Conglomerates*. The most interesting of these is the *osseous conglomerate;* which consists, of rounded quartz pebbles, rarely more than an inch in diameter, with a cement of animal matter? clay, iron, and sometimes a minute portion of carbonate of lime. It abounds in fragments, mostly rolled, of the bones and teeth of animals; some of them very large. It is sometimes as hard, and broken with as much difficulty, as graywacke: but in other places the coherence is not strong.

The strata of this conglomerate are from one to three or four feet thick, and several of them are found distinctly interstratified with the other materials of this cliff.

I cannot find that the like deposit, containing the bones of vertebral animals, occurs in any plastic clay formation described in Europe; although in England, pebble beds alternate irregularly with the sand and clays, but it does not appear that these are consolidated.*

Another variety of conglomerate at Gay Head, consists of pebbles, chiefly quartz, cemented by a great abundance of the hydrate of iron, and often containing hollow nodules of the same. I am not sure that this always alternates with the layers of clay and sand. On account of the great quantity of its debris, that has fallen down upon the face of the cliff, I found it difficult to ascertain its true position in regard to the strata of clay and sand near the right hand part of the Section. I was not without a strong suspicion, that it might lie upon top of the plastic clay; nay, I was led to inquire whether it might not be diluvium consolidated by iron.

A third kind of conglomerate exists at this cliff, in rolled masses, a few inches in diameter, in

* De la Beche's Manual, p. 235. 2d Ed. London, 1832.

the green sand stratum. It occurs, also, very frequently along the beach; having probably been washed out from the cliff. It is unlike any rock that I ever met with. The nodules are almost if not entirely quartz, and the cement a black compact substance, highly bituminous, and slightly effervescing with acids. It appears like bituminous marlite, finely comminuted. As already mentioned, in one piece I found the remains of a Zoophyte.

At the foot of the cliff, I also found rolled pieces of a yellowish gray rock, hard and compact, approaching hornstone. It appears like argillaceous sandstone, which has been subjected to powerful heat by the proximity of trap, such as occurs at Mount Holyoke, on Connecticut river; but I have met with the like rock nowhere else in the State. (No. 81.)

In a kind of ferruginous sand in this cliff, I met with one or two small specimens of a rock of oolitic aspect; (No. 80.) which, however, effervesces but feebly with the acids.

Specimens of all the preceding varieties of clay, sand, lignite, and conglomerate, will be found in the collection made for the Government. (Nos. 62 to 81; also 1715 to 1731.)

## *Description of the Colored Section of Gay Head on Plate 55.*

Rains and gravity have so mingled the various sorts of materials on the face of the cliff at Gay Head, that a cursory observer would see no regular stratification; and so it appears on Fig. 30. But the most careful examination which I have made of the place, results in the conviction that the strata here run nearly N. W. and S. E. and dip from 30° to 50° N. E. Neither the clay nor sand are but rarely laminated. I measured the horizontal width of each stratum along the beach, and applied the clinometer where I could, to get the dip. The colors were put on while upon the spot; and were intended to give a correct idea of the cliff, as it would appear were its surface to be scraped off, so as to show the strata in their unchanged position. The following description will show the composition of the cliff, beginning at the north end.

No. 1. Soil and Diluvium: several rods thick.
" 2. Diluvium: 260 feet.
" 3. Gray Clay with lignite: 100 feet.
" 4. Reddish ferruginous Sand: 100 feet.
" 5. Green Sand, 50 feet: Most of the organic remains are in this stratum.
" 6. Yellowish and dark brown Clay: 150 feet.
" 7. White Sand: 50 feet.
" 8. Clay with Lignite: 50 feet.
" 9. Brown Clay and Sand: 200 feet.
" 10. White and Yellowish Clay with Lignite: 300 feet.
" 11. Red Clay: 110 feet.
" 12. Blue Clay with Lignite: 70 feet.
" 13. Red Clay: 250 feet.
" 14. Brown Clay and Lignite: 50 feet.
" 15. White Sand: 85 feet.
" 16. Red Clay with Lignite: 280 feet.
" 17. Yellowish ferruginous Conglomerate and Sand; the lower part esseous: 200 feet.
" 18. White sand: 265 feet.
" 19. Light Gray Clay and Sand: 66 feet.
" 20. Red Clay: 50 feet.
" 21. Gray Clay: 50 feet.

No. 22. White Clay: 100 feet.

" 23. Gray Clay with ferruginous conglomerate near the top, perhaps not interstratified: 300 feet.

" 24. White Clay: several rods.

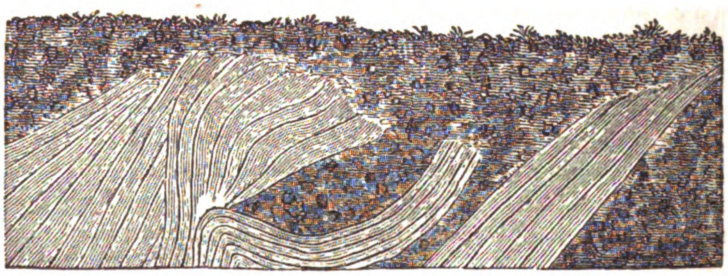
" 25. Red Clay chiefly: a long cliff seen obliquely. The coast here curves rapidly towards the east.

The entire length of the Section is about four fifths of a mile.

## *Other Localities of Plastic Clay.*

At the cliff in the east part of Chilmark, on the shore of the ocean, some of the clay is schistose, and there we find the following section. A considerable part of the cliff there, from 20 to 30 feet high, is covered by diluvium, which has slidden down from the upper part. But where the strata are exposed to view, they present the curved, contorted, and inclined appearance exhibited below. The general dip, it will be seen, is towards the south, as the left hand side of the sketch is the southern extremity of the cliff. The sketch embraces a horizontal distance of about 5 rods.

Fig. 85.



*Section in the Plastic Clay: Chilmark.*

## *Nantucket and Cape Cod.*

Beneath the coating of diluvium, which is represented on the Geological Map as covering Nantucket and Cape Cod, a clay occurs of a bluish color, sometimes with a tinge of green, but quite different in appearance from any that is found at Gay Head. The highest cliffs that I have seen of this clay are at the Light House in Truro, near the extremity of Cape Cod. There the layers are perfectly horizontal; as they are generally, or nearly so, all over the Cape and on Nantucket. I have never found any organic remains in this clay: nor any mineral to identify it with the strata at Gay Head; except some imperfect nodules of hydrate of iron at Truro. It is altogether wanting in the variegated character exhibited by the plastic clay; and though I feel a good deal in doubt as to its position on the geological scale, I am inclined at present to regard it as a newer member of the tertiary strata than the plastic clay, not deposited till the latter had been tilted up. Yet it is possible that it may, like the blue clay in other parts of the state, be a part of the diluvial formation. But I know that the main body of diluvium lies above it, and have no evidence that any drift lies beneath it. Yet as we go north into Plymouth County, we do find gravel beneath similar clay: though it may not be diluvial gravel. But I have said all that I wish on this subject in giving the lithological characters of diluvium. At present I rest in the opinion, that probably the plastic clay may exist beneath a considerable part of Nantucket and Cape Cod; but it is concealed by a more recent tertiary, or a diluvial deposit.

## *In Marshfield and Duxbury.*

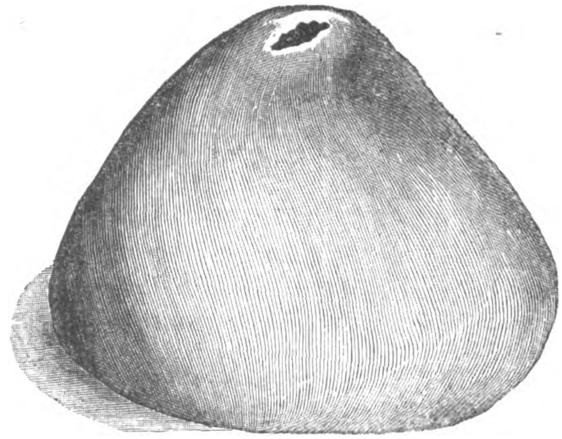
In the Economical Part of my Report, page 91, I have given all the details that are necessary perhaps, respecting a stratum of green sand in Marshfield and Duxbury, a little beneath the surface. The region is one of granite and sand, and as unpromising as any in Massachusetts for finding such a substance. Yet there it is, very similar in appearance and composition to the stratum on Gay Head. It abounds too, with the same fossils; viz. casts of a Cytherea and a Turbo, and bones of a vertebral animal, and the tooth of a shark. Rev. Benjamin Kent of Duxbury first called my attention to the subject: and the strata which he penetrated in reaching the sand, were first, diluvium; then vegetable earth; then a few inches of tough blue clay; then layers of ferruginous conglomerate; then green sand. This may be the same stratum of green sand as has been described at Gay Head: but as that is evidently the result of the abrasion of some previous similar deposit, this also may be another stratum of the same kind, higher up in the series: and, therefore, these facts do not necessarily show that the plastic clay formation exists at this spot; although they do render it probable. My own belief is, that as we go northeasterly, the Eocene tertiary strata sink lower and lower; and that they have been found above the waters at no point beyond Gay Head. As we go south, the cretaceous rocks, which lie immediately beneath the Eocene Tertiary, emerge above the waters in N Jersey, and continue through most of the southern states, often covered by the tertiary. Whether they gradually rise higher and higher as we proceed south, I know not. But in South America they occur, probably a continuation of the North American group—at the height of 12000 French feet. (*Petrifications recueillies en Amerique*, &c. *decrites par Leopold de Buch, p.* 3 *and* 4, *Berlin*, 1839.) It is a curious fact, however, that throughout this vast extent no real chalk has ever been found.

## *Mineral Contents.*

The most interesting and abundant mineral at Gay Head, is limonite, or the hydrate of iron. The varieties are all argillaceous. The most important are the following.

1. *Nodular.* This is the most abundant variety, and the nodules vary in size, from that of a walnut to a foot in diameter. Sometimes they are spherical, more frequently ovoid; sometimes ovoid flattened; sometimes composed of concentric layers of the compact oxide and yellow ochre with a nucleus sometimes of sandstone in the center, but more frequently hollow. These nodules are generally mixed with a large proportion of coarse sand and gravel, which unitedly form, as already remarked, a conglomerate. The flat nodules are sometimes slaty; and it is on the laminæ of these, that the principal part of the vegetable remains of this formation occur. Sometimes the nodule, when broken open, is seen to envelope a flattened mass of lignite: showing conclusively that the ore originally accumulated around this as a nucleus. (Nos. 121, 122, 123.) Fig. 86 shows one of these concentric nodules very much resembling a pear or a squash. It is 6 or 7 inches in diameter and has a central axis of lignite.

Fig. 86.



Nodular argillaceous iron ore exists also on Nantucket; as well as in other places on the Vineyard.

2. *Columnar.* Some of the larger nodules mentioned above, being broken open, exhibit, as the result of desiccation, a columnar structure in the interior: the columns varying in diameter from a quarter of an inch, to one, and even two inches; and in length, from half an inch to three inches The sides are generally unequal in size, and various as to their number. The axis of the column is always parallel, I believe, to the shortest diameter of the nodule. The space between the columns is generally only sufficient to allow of the introduction of the blade of a penknife. In some instances, where a shrinkage has taken place, no regular forms are produced: but the seams run in all directions. I have not observed any case where the seams reach to the surface of the nodule. The outer portion, from half an inch to an inch thick, is compact gray iron stone.

An examination of these nodules, leads one at first almost irresistibly to the conclusion, that they must have been once in a melted state, and suddenly cooled at the surface: and the glazed iron-black appearance of their internal surface, tends to confirm this opinion. And yet, I doubt whether it is necessary to evoke the god of fire for a solution of this phenomenon. For the mere desiccation of nodules, containing so much argillaceous matter, will, it seems to me, adequately explain the appearances. Of course the external portion would first part with its moisture and become solid: and as the water gradually escaped subsequently from the interior, the shrinking would produce fissures within; since the already compacted crust would not permit the compression of the whole mass. And as to the shape of the pieces, resulting from the shrinkage, it seems to me that if the nodule be spherical, the fissures will coincide essentially with planes passing through the center of the sphere. (See No. 126.) But if the shape be that of a flattened ellipsoid, the greatest shrinkage must take place in the direction of the plane, which coincides with the two longest diameters of the ellipsoid: and, therefore, most of the fissures will be made perpendicular to that plane, so as to produce columnar masses; although there will be a proportionable shrinkage in a direction perpendicular to the plane above mentioned, which will produce at least one termination to the columns: and all the specimens which I have examined, confirm this rationale of the appearances; (See Nos. 124, 125,) as does also the desiccation of clay on the surface of the earth, producing columnar masses, which stand perpendicular to the horizon. I apprehend it will be found, that the true columnar structure exists only in those nodules which are flattened.

The existence, sometimes, of lignite in the center of these nodules, is another evidence that they never could have been completely fused, since the pieces of wood that were enveloped, must have been entirely destroyed. I am aware that coal is sometimes found in trap rocks, or between the trap and sandstones: but in such cases, I apprehend that the fusion of the trap was only partial, as we know to be the case with many lavas.

Further: how could nodules of iron, in the midst of clay and sand beds, have been exposed to a fusible heat, and yet the clays and sands have remained unconsolidated?

3. *Mamillary.* The tubercles of this variety are rarely smaller than a buck shot, or larger than an ounce ball. When broken, they exhibit no appearance of a radiated structure; but are massive, though scales of mica and grains of sand are observable in every part of this ore. (No. 120.) I am informed by Thomas A. Green, Esq. that it exists in much larger quantities in the cliffs, four miles east of Gay Head, in the west part of Chilmark, a little east of Minimshi Bite, than at Gay Head, where I found it.

4. *Pisiform.* The grains are rarely exactly spherical, and seldom exceed the size of a small pea. Not unfrequently they are distinctly reniform. Color, externally, blackish brown; internally, yellowish brown. Aggregated into irregular masses with clay and gravel. This ore seems sometimes to be the mineralizer of alcyonia, shells, &c. It is not abundant. (No. 119.)

5. *Ochrey Brown Iron Ore.* This occurs mixed sometimes with every variety above described: particularly with the nodular. But it is never seen in large masses.

It is well known that the preceeding are valuable ores of iron for smelting; and at Gay Head, particularly, they may be obtained in abundance. That spot is still in possession of the descendants of the Indians of Martha's Vineyard: and it is to be hoped that the Government of the State will take measures to prevent their being defrauded of this ore, which may prove of considerable value.

*Radiated Sulphuret of Iron.* This is very frequent and beautiful in the osseous conglomerate and blue clay of Gay Head. The nodules are sometimes perfect spheres; from one to three inches in diameter; but generally more or less irregular; the surface often exhibiting one face of numerous cubic crystals; but on breaking the mass, the radiation is obvious. Such, however, is the tendency of this ore to decomposition, that it is difficult to preserve specimens long in a cabinet, unless excluded from the atmosphere. Their decomposition produces of course sulphate of iron and sulphate of alumina and potash, or alum, which effloresce on the clay. (Nos. 117, 118.)

*Sulphate of Lime, or Selenite,* exists at the same place in tables and acicular prisms, disseminated in blue clay and in lignite (No. 131.)

It is said that amber has been found floating in the ocean near the cliff at Gay Head. I also found it in small quantities, connected with a vegetable relic in iron ore, at the same place. At Nantucket, a mass of light colored amber was found, three or four inches in diameter, which is now in the cabinet of T. A. Greene, Esq. of New Bedford.

Native arsenic is said to have been found at Gay Head: but I saw none.

## *Organic Remains. Fossil Vegetables.*

The lignite beds already described, prove the presence of a large quantity of vegetable matter in this formation. This lignite is sometimes ligniform, of a brown color, and distinctly fibrous: sometimes it is hard and brittle; and more commonly, it is friable. I found a mass at the foot of the cliff, which abounded in the impressions of a monocotyledonous plant, bearing the closest resemblance to a Zostera. The mass resembled peat.

But most of the vegetable impressions at this cliff are dicotyledonous; and exist only in slaty argillaceous iron ore. Although these impressions are very distinct, exhibiting the minutest reticulations of the leaf, yet every particle of the vegetable substance is removed. This is true

only in those instances where the impressions are leaves. (Plate 19, Figs. 1, 2, and 3.)* The shape of most of these leaves very much resembles that of an Ulmus: but they are wanting in the serratures, which the existing species in this country possess. Fig. 3, has serratures, or rather is crenate, and resembles a Salix. On Fig. 2, may be seen the impressions of pear shaped seeds.

Figs. 4, and 5, represent different individuals of another variety of vegetable remains, occurring at the same spot, and in the same iron ore. These are not mere impressions; but a scale of carbonaceous matter, mixed with amber, marks the spot where the vegetable was imprisoned. The amber occupies longitudinal ridges, which in the plate are represented by white stripes. It seems to me very obvious, that these remains must be the seed vessels of coniferous plants. The amber shows that they abounded in resin. They resembled unopened flowers of syngenesian plants: but they contain too much resin for these; and have left too much undecomposed matter for so frail a substance. Indeed, although the compound flowers, with their double calyx and strong receptacle, might stand a better chance of being preserved in a fossil state than those of any other kind of plant, yet I am not aware that a flower of any sort has been found in that condition. Near one of the specimens of the vegetable under consideration, I observed an ovoid seed vessel, about a quarter of an inch long, exhibiting the shell most distinctly, and different from the pear shaped ones just mentioned.

## *Animal Remains.*

*Vertebral Animals.* The bones and teeth of these Animals are more numerous at Gay Head than any other organic relics. They are found in the greatest abundance in the osseous conglomerate, already described: but they occur also in the green sand, and in a yellowish sand, associated with the green sand. For the most part, the bones are not mineralized; but frequently they are black when broken; and sometimes they are thoroughly impregnated with iron ore. In general they are much broken and often rolled. In one instance, however, I noticed a succession of large vertebrae, one or two occasionally being absent, for a distance of 10 or 12 feet. Some of these are 9 inches thick, and as much in length. (Nos. 104 to 108.) The head in this instance was wanting; and, indeed, nearly all the other bones, except the vertebrae, and short portions of the ribs. (No. 109.) But it is improbable that these could have been moved in so connected a state, far from the spot where this huge animal died. In the green and ferruginous sand, vertebrae are found only occasionally; and they are generally much smaller than those in the conglomerate.

Two of these vertebrae, among the smallest, are exhibited on Plate 19, figs. 6, and 7. Pieces of the ribs, (some of them 4 or 5 inches in their greatest diameter,) bones of the head, &c. are in general so broken, that a sketch of them would be useless They will be found among the specimens. All the vertebrae that are drawn, are from the green and ferruginous sand.

All the varieties of teeth that accompany these bones, which I could find at Gay Head after a protracted search, are exhibited on Plate 19, Figs. 8, 9, 10, 11, 12, and 13. Figs. 8 and 9, are of a triangular shape, yet like the others, they probably belonged to different genera of sharks. Figs. 8, 9 and 10, may have belonged to the Carcharias of Agassiz; and figs. 11 and 12, to his Lamna. Fig. 14 was from the green sand of Duxbury, and appears to have been a Lamna. In general these teeth are very much broken, and never have I seen them attached to the jaw. This fact confirms what all the other organic relics at Gay Head teach, that they must have been subject to a good deal of violent action by the waves during their deposition.

Fig. 13 may have been a part of the crocodile's tooth, as it corresponds with one figured in Cuvier's *Ossemns Fossiles*. But it may, also, have been the tooth of a Sauroid fish, such as the Megalichthys, which had large conical striated teeth, like fig. 13. These fish are, indeed, found

* All the organic remains that are figured are drawn of the natural size.

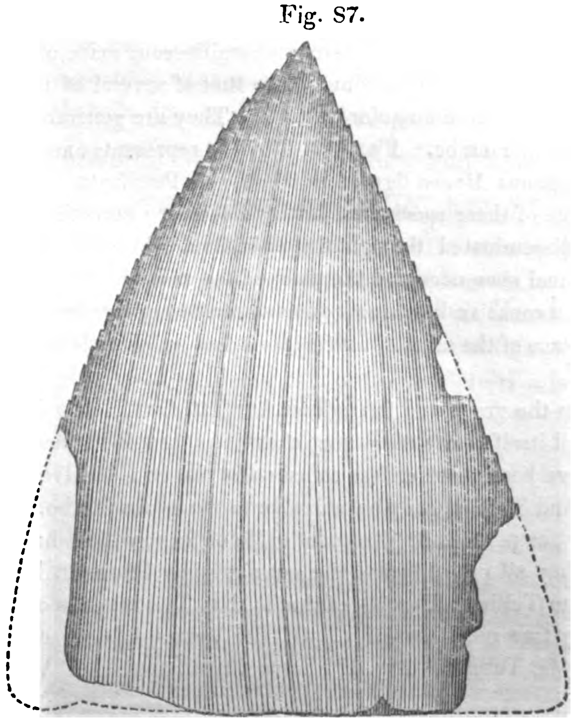
far beneath the tertiary strata. But the specimen from Gay Head, which is only a fragment, is converted into a substance exactly like flint, being in this respect unlike all the other petrifactions from that place; and therefore, it may have been derived from a formation even as old as the Carboniferous. (*No.* 103.)

It ought to be noticed, that sometimes masses of lignite are contained in this osseous conglomerate; and that in two instances, I found the bones penetrated by a cylindrical cavity, two or three inches long; pretty obviously the work of some lithodomous shell. (Nos. 112 and 116.) None of the vertebrae or other bones which I have described except the teeth, so far as I can judge from the imperfect means within my reach, seem to be those of the shark. They bear a much nearer resemblance to those of huge saurian reptiles: one of the vertebrae in particular, appears very much like those of the Plesiosaurus.

A tooth of the shark (probably a Carcharias,) from Gay Head, much larger than those which I have described, is preserved in the Collection of the Essex County Natural History Society at Salem. I am indebted for the following sketch and description of it to Professor Charles B. Adams of Middlebury College.

"I have before me a shark's tooth of extraordinary dimensions, of which you will find below a figure, of the natural size. The specimen is from Gay Head, Martha's Vineyard, and belongs to the Essex County Natural History Society. It is 3 1-2 inches in length, and probably might have been longer, as the base is imperfect. The sides are broken off for some distance above the base, as represented in the figure, but the apicial angle between the sides indicates a base not much less than the length. 2 3-4 inches on one side, and 2 1-4 on the other, are nearly perfect, and the edges are minutely crenulate, rather than serrate. The surface represented in the figure has a convexity of 1-3d of an inch. The enamel is perfect, with the exception of a number of longitudinal cracks, which terminate about 1-3d of an inch, before reaching the edges of the tooth, the middle one however extending to the apex. The other side has a less convexity, and rises with an inclined plane each side, about 7-8ths of an inch, but is rounded in the middle The enamel on this side is also cracked.

Fig. 87.



***Shark's Tooth from Gay Head.***

"A portion of osseous conglomerate adhering to the base of the tooth, shews that it was taken from the stratum of the conglomerate, which you have described in your Report on the Geology of Massachusetts.

"What a monster! The lowest estimate would make this shark more than 60 feet in length: and the estimate according to the rule which you have cited, of Lacepede and Faujas St. Fond, would make him 88 feet long. What a mouth! With an opening 6 or 8 feet wide, thickly serrated with several rows probably, of these enormous teeth.

"Last summer Pardon G. Seabury, Esq. of New Bedford informed me that he had seen at Martha's Vineyard a few days previous, a shark's tooth 3 inches in length."

In the north part of Chilmark, on the road to Tisbury, on Martha's Vineyard, an excavation by the road side has brought to light the osseous conglomerate, and Dr. Gale of Holmes' Hole, obtained there several shark's teeth. One of them was 4 inches across the base, and four inches high, including the roots. It would seem that such huge fishes as Professor Adams has described, were not uncommon once on the coast of Massachusetts. In comparison it will hardly be proper for us to speak of any of the present puny inhabitants of the ocean as monsters of the deep, unless the famous sea serpent should prove as gigantic in possession, as he long has been in the newspapers.

*Crustacea.* In the green sand at Gay Head we meet with well characterised specimens of the genus Cancer: although they are in general much broken; showing that they originally belonged to a formation which was abraded or destroyed anterior to the production of the green sand. The interior part of the specimen consisted of argillaceous matter, probably containing a large proportion of oxide of iron: but the covering of the animal still retains its black shining color, although apparently carbonaceous. The broken state of nearly all the specimens, renders it difficult to determine whether they belonged to more than one species, although they probably did: and for the same reason I have thought that drawings would not be of use.

*Zoophyta.* In the bituminous conglomerate that occurs in rolled masses in the same green sand, I found a branching zoophyte, whose characters are indistinct.

In the same green sand, and also in the ferruginous sand associated with it, we find numerous concretions whose interior part appears to be compact argillaceous oxide of iron, with the pisiform ore disseminated. Their shape is so exceedingly like that of several of the alcyonia, that I suspect they are petrifactions of those singular animals. They are generally more or less rolled, though not as much so as the crabs. Plate 19, Fig. 15, represents one of these relics. It resembles a species of the genus *Manon* figured in Goldfuss's Petrifacta.

On the surface of some of these specimens small pebbles are sometimes seen; and I have occasionally found them disseminated through the specimen. In such case it may reasonably be doubted whether an animal once occupied the place of the nodule. Yet if the principal part of it be hydrate of iron, I can conceive how a few pebbles might be introduced along with the iron as it gradually took the place of the animal. Still, I am not in a little doubt as to the origin of these nodules.

*Testacea.* I found in the green and ferruginous sand at Gay Head, the casts of three genera of shells. As the shell itself is wanting, the characters are indistinct; and there is evidence that the specimens have been more or less rolled; but the two bivalves are probably referable to the genera Venus and Tellina, and the univalve to the genus Turbo. The mineralizer is the same ferruginous clay, or perhaps argillaceous oxide of iron, which has petrified the crabs and zoophytes. Hence they all probably had the same origin. Plate 19. Fig. 16, is a sketch of the Venus: Fig. 17, of the Tellina: Fig. 18, of the Turbo. The latter is obviously somewhat broken. I could find only two specimens of it. Of the Venus, I found only three or four; but I obtained 20 or 30 of the Tellina. Fig. 19 shows a small species of Venus from the green sand of Duxbury.

## *Theoretical Considerations.*

It is universally agreed that all the tertiary formations have been deposited from materials diffused or dissolved in water; and it is now generally admitted that these deposits took place in independent basins and at various epochs. One of the most remarkable facts in relation to these deposits, is the frequent alternation, or admixture, of marine with fresh water or terrestrial relics. Thus, at Gay Head, we have lignites and dicotyledonous vegetables mixed and probably alternating with the remains of sharks, alcyonites, crabs, and marine shells. In some instances, such facts may be explained by supposing alternate elevations and depressions of the surface, so as to bring salt and fresh water successively over these deposits. But more usually it is probable these strata were deposited in estuaries, which were occasionally inundated by fresh water: and as in early times the earth's surface was perhaps, more level than at present, these inundations might be more extensive than any that now occur.

The inclined position of the Eocene Tertiary on Martha's Vineyard, especially at Gay Head, is extremely difficult to explain. I have no evidence of any disturbance by which the strata in any part of New England have been elevated more recently than the tilting up of the new red sandstone along Connecticut river: Nor in the eastern part of the state is there any other evidence than this plastic clay presents, of any rise of the strata since the elevation of the graywacke. Yet this disturbance at Gay Head must have been immensely more recent: and I have been led to enquire, whether it be not possible that it might have resulted from the sliding down of the clay and sand towards the sea, after they had been undermined. This to be sure is extremely improbable; and little less so is any supposition which I can make.

## *Supposed Volcanic Action at Gay Head.*

The opinion, I ought, however, to remark, has been advanced by writers too respectable to be passed unnoticed, that there are traces of volcanic action at Gay Head. The great quantity of lignite there mixed with the clay, giving the whole mass an appearance somewhat like cinders, and the ferruginous conglomerate, in which the pebbles are coated over with the brown hydrate of iron, often exceedingly resembling the conglomerated semi-fused mass that is raked out of a furnace, would very naturally lead a person, unpractised in geology, to refer them to volcanic agency. These are undoubtedly the substances intended by Dr. Baylies, when he speaks of "masses of

charcoal," and "large stones, whose surfaces were vitrified,"* It is now well understood, that neither lignite nor the hydrate of iron, require heat for their production.

### 4. NEW RED SANDSTONE.

Under this name I have included all the sandstone in the valley of the Connecticut; extending from New Haven, Ct. to the north line of Massachusetts in Northfield. On a geological map, given in the 6th volume of the American Journal of Science, I have marked the inferior beds of this formation as Old Red Sandstone. Nor do I now deny the existence of this rock in that valley. But I have not discovered marks enough to identify it, so as to be justified in giving it a place on the Map.

In Europe the Coal Measures usually intervene between the old and the new red sandstone: and some geologists have thought that we have all three of these formations in the valley of the Connecticut. Thin seams of coal do, indeed, occur in this sandstone; and many specimens of rock may be found, which cannot be distinguished from the shales and sandstones of the coal measures. But in general, the flora of this sandstone is altogether of a different character from that connected with the coal formation, and very scanty. I cannot, therefore, present any, conclusive evidence of the existence in this valley, either of the coal measures, or the old red sandstone. But I think I have proof sufficient to justify me in maintaining that the New Red Sandstone does exist there. That proof I shall now present. In order, however, to make my arguments intelligible, it will be desirable to describe briefly the extent of this formation in this country.

In the valley of Connecticut river this formation commences at New Haven on Long Island Sound, and extends uninterruptedly across Connecticut and Massachusetts; beyond which State it does not occur. In going southerly we again meet with it in New Jersey; from whence, with little interruption, it extends across Pennsylvania, Maryland, and Virginia, into North Carolina. Throughout this whole extent, its lithological characters are so much alike, that the geologist recognizes it at once as the same formation. It is also traversed by dykes, or irregular protruding ridges of greenstone; and at the junction of the two rocks, ores of copper are common. The organic remains also, especially the fishes, correspond essentially in the different parts of this formation. In Nova Scotia, likewise, a similar red sandstone occurs; which is connected with trap rocks, contains gypsum and salt springs, and is underlaid by a coal formation. That this is the new red sandstone can, therefore, hardly admit of a doubt. Let us now look at the

* Transactions of the Amer. Acad. of Arts and Sciences, Vol. II. Part I. p. 150.

evidence which goes to show that the sandstone of the Connecticut valley belongs to the same place in the geological scale.

1. *Lithological Characters.* In order to make fair comparison, after having become familiar with the numerous varieties of this formation in the Connecticut valley, I cast my eye over a collection of 600 specimens, extending through the entire geological series of rocks, as they are developed on the continent of Europe. My object was, to ascertain whether there was any such resemblance between the New England group, and any one of the European formations, as would at once arrest the attention, without looking at the labels. It was obvious at once, that no such resemblance could be traced, except in a group of 60 or 70 specimens, near the middle of the series: and here it was so striking, that one could not but infer that they must have been formed under similar circumstances. In both groups there was a great variety of colors, red, brown, gray, white, and black; yet the red predominated. In both groups these colors were arranged in stripes, spots, or clouds; so as to give a lively variegated aspect even to hand specimens: and in both groups were fine shales and marls, common gritty sandstones, limestones, conglomerates, and breccias. I think the calcareous matter decidedly more common, however, in the European group, and that the sandstone is oftener of a light colour; but that a slaty character is much more common in the New England series.

The European collection to which I have referred, is one of those put up at the Mineralogical Institution at Heidelberg, in Germany; and is deposited in the Cabinet of Amherst College. And as similar collections are widely distributed in this country, as well as in Europe, and have the same numbers and labels attached to similar specimens, it may be well, perhaps, to refer to a few of them, for the sake of comparison with those from Massachusetts in the state collection. I shall mention only those which are so exactly alike, that the one might be substituted for the other, and the eye not be able to detect the difference. I shall give the labels that are attached to the specimens from Germany.

No 267. "*Lower Keuper Marl*: black, covered by the keuper gypsum, and alternating with its lower strata. Wurtemburg." Compare with Nos. 202, 203, state collection; which are the common, dark, not very fissile shale so common in the Connecticut valley, and found most abundantly near the middle of the formation.

No. 269. "*Keuper Sandstone*, forming the middle strata of this formation. Dolerite breaks through this rock. Weiler, Baden." Compare with Nos. 171, 172. This gray sandstone in the Connecticut valley is usually found very near where trap rocks have been forced through the formation.

No. 320. "*White Sandstone*, variety of New Red Sandstone called *weisses Todt-Liegendes*, full of small laminae of mica and fossil remains of plants belonging to Lepidodendron Dichotomum, (Sternberg,) partially overlying the new red sandstone called *Rothes Todt-Liegendes*, or mica slate, or gneiss. Spessart." Compare with 248.

No. 297. "*Sandstone of the Vosges* (Voltz.) It passes in several places into the variegated Sandstone. Neiderheins." Compare with Nos. 165, 166. In an Economic collection in Amherst College from Heidelberg is a specimen (No. 155) called "Gres vigarre, Heidelberg, Bade," which corresponds exactly with Nos. 165, 166.

Nos. 318, 319. "*Bituminous Marl Slate:* the lowest of the formation of the first floetz limestone. Immediately covering the white sandstone (variety of new red sandstone) called *Weiss Liegendes.* Eisleben, Mansfeld." Compare with Nos. 207, 208 and 278. This is the rock, which, both at Mansfeld and in Sunderland, contains fossil fishes.

No. 322. "*New Red Sandstone, or Conglomerate*: immediately below the bituminous marl slate. Specimens thereof are not to be distinguished from many variegated sandstones. Hesse." This is a variety of the *Rothes Todt-Liegendes* of the Germans, and of the *Gres Ancien* of the French. Compare with No. 1752. Very common about the center of the Connecticut Valley.

No. 323. "*Rothes Todt-Liegendes: New Red Sandstone Conglomerate:* including various fragments of older rocks of the neighboring Odenwald. Probably overlying gneiss. Hesse." Also No. 156 of the Economic Collection, which is labeled, "Keuper Sandstone, Malsch, Bade." Compare with Nos. 134 and 1736. This is that variety of the lower beds in the Connecticut Valley in which the fragments of feldspar appear to be more or less converted into porcelain clay. It generally lies near the primary rocks, and is nearly the oldest variety of sandstone in this valley.

Nos. 324, 325. "*Rothes Todt-Liegendes:* New Red Sandstone, or Conglomerate, with fragments of clay slate, gneiss, &c. It overlies clay slate and transition limestone. Baden." Compare with Nos. 137, 138, 139.

No. 132 of the Economic Collection, which is labeled, "Muschelkalk: Harmersheim, Bade." Compare with No. 215, which is the fetid limestone of West Springfield.

There is also at Amherst College, a collection of the rocks of continental Europe, amounting to 200 specimens, put up at Heidelberg. Compare No. 94 of this Collection, which is labeled, "the true Zechstein, Eisleben, Thuringia," with Nos. 213, 214 of the State Collection, which are the fetid limestone from West Springfield.

Compare also No. 98 of the same European collection, which is labelled, "Weiss legendes, Ruokingen, Hanau," with Nos. 136, 137 of State collection. This is the same as No. 320 of the European rocks already described, except that it is coarser.

I might go on to multiply examples of this resemblance still farther. But it is unnecessary. I have also compared a pretty extensive collection of specimens from the red sandstone of Nova Scotia with those from Germany, and I think the resemblance even more striking than in the rocks of the Connecticut valley: partly, I apprehend, because the Nova Scotia rocks contain gypsum.

I have not had access to so full a collection of specimens of the new red sandstone of Great Britian as of Germany. So far as I have compared them, there is a strong resemblance to those of the Connecticut valley.

The correspondence between the German and New England specimens is most striking in that part of the formation which the Germans denominate *Rothes Todt-Liegendes,* or *red dead lyer;* which constitutes the lowest part of the New Red Sandstone Group, lying immediately upon the coal measures. And it is interesting to know, that all the specimens above referred to in the State collection, as corresponding with the Rothes Todt-Liegendes, are from the lower part of the formation in the Connecticut val-

ley. These lower beds are much less slaty than the upper ones, and their color is more uniformly red. In general the ridges of greenstone separate the thicker from the more slaty beds. The rock above, or on the east side of the greenstone, is much more various in its characters and composition; being made up sometimes of fine shales, than of slaty sandstones, then of coarser sandstones, then of limestone; and finally of very coarse conglomerate.

I am aware how little dependance can be placed upon lithological characters alone, in determining the place of a mechanical rock. But if on comparing the organic remains and the relative position of a rock, (which are the other important characters for identifying it,) we find them agreeing with the same known rock as do the lithological characters, our confidence in the conclusion at which we arrive, is strengthened. Let us then see how it is in the present case.

2. *Organic Remains.* The organic remains in the red sandstone of the Connecticut valley are very few, and most of them are still undetermined. In regard to the plants, of which a few species occur, I can only say that they appear to be entirely unlike those of the coal formation; and some of them, I think, without doubt, are dicotyledonous. Some of them may be large fucoids. Among the animal remains, by far the most important are several species of fish, of the order Ganoides, belonging to Agassiz's genera *Palæoniscus* and *Eurynotus.* Now these fish are abundant in the New Red Sandstone of Europe; not less than a dozen species being described by Agassiz in that group. Indeed, specimens from the Connecticut valley so much resemble some from the bituminous marl slate of Germany, that none but practised eyes could discern any difference. But they also occur in the coal formation, and, therefore, their existence in our sandstone does not certainly prove that it is the new red sandstone. I think, however, we have the means of deciding this point; as I shall show when I consider the relative position of our sandstone.

I cannot but regard the paucity of organic remains in the sandstone of this valley, as a presumptive proof that it is the new red sandstone. For such is its character all over Europe.

Another presumptive argument on the same side, may perhaps be derived from the discovery of the bones, not mineralized, of a vertebral animal, as much as five feet long, in this sandstone, in Connecticut. These bones were certainly not those of fish; and I believe that hitherto the remains of no other vertebral animal have been found lower than the new red sandstone.

A similar argument is derived from another fact. In no less than six instances have the tracks of animals been found upon sandstone in Europe; and in every case except one, they occur upon the new red sandstone. Such

impressions are very numerous upon the sandstone of the Connecticut valley; and the probability is strong that this also is an equivalent rock.

The evidence thus far is only probable, not decisive. Let us see if the last test is not more satisfactory.

3. *Relative Position.* As the sandstone of the Connecticut valley reposes directly upon primary rocks, and is covered only by diluvial and alluvial deposits, its exact place in the complete geological scale cannot be directly determined. But in New Jersey, Pennsylvania, and Virginia, Professors William B. and Henry D. Rogers seem to have satisfactorily determined that this same formation lies above the coal formation. *(Prof. W. B. Rogers' Report for* 1839, *upon the Geology of Virginia, p.* 71, 72.*)* Now the fossil fishes found in this formation at Deerfield, West Springfield, and Sunderland in Massachusetts; at Glastenbury, Middletown, Berlin, Durham and Southbury in Connecticut; and of Morris County in New Jersey, belong to that division of Agassiz's classification, which he calls *Heterocerci;* that is, having tails with unequal lobes, and called *unsymmetrical, or heterocercal.* In these the scales, and probably the vertebrae, extended to the extremity of the upper lobe. Such fish have been found rarely, if at all, in any formation above the new red sandstone. Hence then, the rock containing them in Massachusetts, Connecticut and New Jersey, must be as old as the new red sandstone. But the Professors Rogers have shown that it lies above the coal formation. I do not see, therefore, but it must occupy the place of the new red sandstone; since this is the only rock between the lias and the coal.

It may serve to illustrate this argument more fully, to present a synopsis of the distribution of the order of fishes which Agassiz denominates Ganoides; and which embraces all those with rhomboidal or polygonal scales. It was derived from his great work on fossil fishes now in the course of publication: and for it I am indebted to my young friend, Mr. John H. Redfield of New York, so favorably known by his researches upon the fossil fishes of this country.

GANOIDES.

1. *Old Red Sandstone.*

| | |
|---|---|
| Cephalaspis, 4 species, | Osteolepis, 1 species. |
| Gyrolepis, 1 " | Total 6. |

2. *Coal Measures.*

| | |
|---|---|
| Dipterus, 2 species, | Osteolepis, 2 species. |
| Acanthodes, 2 " | Cheirocanthus, 2 " |

| | | | |
|---|---|---|---|
| Cheirolepis, | 2 species. | Palæoniscus, | 10 species. |
| Amblypterus, | 7 " | Eurynotus, | 2 " |
| Pygopterus, | 1 " | | Total, 30. |

### 3. *Rothe Todte Liegendes.*

Palæoniscus, 2 species. Total, 2.

### 4. *Magnesian Limestone and Zechstein.*

| | | | |
|---|---|---|---|
| Palæoniscus, | 8 species. | Platysomus, | 5 species. |
| Pygopterus, | 3 " | Acrolepis, | 1 " Total, 17. |

### 5. *Gres bigarre, Muschelkalk, and Keuper.*

| | | | |
|---|---|---|---|
| Amblypterus, | 1 species. | Gyrolepis. | 3 species. |
| Eurynotus, | 2 " | Palæoniscus, | 1 " |
| Saurichthys, | 1 " | Placodus, | 2 " Total, 10. |

The species of the above genera are all heterocercal. Those which follow, from the lias upwards, are homocercal.

### 6. *Lias, Oolite, and Calcaire Jurassique.*

| | | | |
|---|---|---|---|
| Leminotus, | 6 species. | Lepidotus, | 11 species. |
| Pholidophorus, | 13 " | Ophiopsis, | 2 " |
| Microps, | 1 " | Notagogus, | 4 " |
| Ptopterus, | 1 " | Dapedius, | 5 " |
| Tetragonolepis, | 16 " | Amblyurus, | 1 " |
| Ptycholepis, | 1 " | Sauropsis, | 2 " |
| Pachycomus, | 2 " | Thripops, | 4 " |
| Caturus, | 9 " | Leptolepis, | 11 " |
| Megalosus, | 2 " | Saurostomus, | 1 " |
| Aspidorhynchus | 6 " | Belonostomus, | 6 " |
| Macrosenius, | 1 " | Sphaerodus, | 2 " |
| Gyrodus, | 10 " | Microcodon, | 5 " |
| Pycnodus, | 4 " | | Total, 126. |

### 7. *Purbeck, Wealden, Green Sand, and Chalk.*

| | | | |
|---|---|---|---|
| Lepidotus, | 5 species. | Macropoma, | 1 species. |
| Sphaerodus, | 2 " | Gyrodus, | 1 " |
| Pycnodus, | 6 " | Dercetis, | 1 " Total 16. |

8. *Tertiary.*

| | | | |
|---|---|---|---|
| Sphaerodus, | 2 species. | Pycnodus, | 2 species. |
| Diodon, | 1 " | Ostracion, | 1 " |
| Blochius, | 1 " | Calamostoma, | 1 " |
| Syngnathus, | 1 " | | Total 9. |
| | | Grand Total, | 200 Species. |

In the fourth volume of the Annals of the New York Lyceum, (p. 37.) Mr. Redfield has described a new genus of fossil fish from Middletown, under the name of *Catopterus gracilis*; and he represents it, though not without doubt, as having a homocercal tail. But in a recent private communication, he says: "In my paper upon the genus Catopterus, I stated, that in Agassiz's arrangement, it would come under the *homocercal* division of his family Lepidoides. This statement was made with a great deal of hesitation; and I now feel disposed to qualify it somewhat. The fact is, that this genus seems to occupy a sort of intermediate position between the two divisions: neither being exactly equilobed, like the *Homocerci*, nor yet having the decided heterocercal character which belongs to those genera which Agassiz has placed in that division. But from the strong analogies, which, in other respects it bears to the heterocercal fishes, I am inclined to think it should go among them."

Rhombic polished fish scales have been found in the bituminous slate of the red sandstone at Farmsville and Leaksville in North Carolina; and in Fauquier County in Virginia; and there can be hardly a doubt but they also belong to the same family of fishes as those above described in the states farther north. Nor can we hesitate, I think, to conclude that all which this rock has furnished, belong to the heterocerci. Now is it credible that all such fishes in Europe should occur below the lias, and the same not be true in this country. It seems to me that this fact fixes the upward limit of the red sandstone under consideration. And since the Professors Rogers seem to have fixed its lower limit, I do not see how to escape the conclusion, that it is the New Red Sandstone Group of Europe. Whether we shall be able to identify all the subdivisions of this wide series of strata, I am not prepared to say: though I am inclined to believe that the representatives of most of them will be found here.

The great importance of the question as to the age of this sandstone, is my apology for having dwelt so long upon it. If it be new red sandstone, it would not be judicious to undertake expensive explorations for coal in it: but rather to seek for gypsum and rock salt. In a scientific point of view, this decision is of great interest; not only because it fixes the age of a very extensive formation in our country, but also, when considered in connection

with the fossil footmarks found upon it, to be described hereafter, carries back the exitsence of one class of vertebral animals to much a earlier period than they had been supposed to have appeared.

## *Lithological Characters of the New Red Sandstone.*

'Taken as a mass,' says De la Beche,* 'the group (of new red sandstone) may be considered as a deposit of conglomerate, sandstone, and marl, in which limestones occasionally appear in certain terms of the series; sometimes one calcareous deposit being absent, as the muchelkalk is in England; sometimes the zechstein, as in the east and south of France; and sometimes both being wanting, as in Devonshire.' 'The beds' says Dr. Macculloch,† 'are sometimes of a conglomerate structure, at others a fine sandstone, and occasionally schistose; and in composition, the rock is calcareous, argillaceous, or ferruginous, or all together; presenting endless varieties of aspect and color.'

These descriptions correspond in general to the group which I denominate new red sandstone in the Connecticut valley. Our rock, however, is more deficient in calcareous matter than is usual in Europe: though more or less of lime is disseminated through all the members of the group; so that in some cases even the reddish shales slightly effervesce with acids: and might, therefore, be properly called *red marl*. Nearly all the limestone in the group is highly fetid; though in some instances this passes into that which is bituminous; and even into bituminous marlite.

It should be recollected, also, that this formation is wanting in gypsum and rock salt; two minerals found in it almost universally: though as mentioned in the first part of my Report, a minute quantity of the former has been found at West Springfield, and South Hadley. I have, however, compared a suite of specimens from the new red sandstone containing gypsum in Nova Scotia, with a suite from the Connecticut valley, and with the exception of the limestones, they can hardly be distinguished from one another. Indeed, why may we not suppose gypsum and rock salt to be occasionally wanting in this formation, as well as limestone?

The following distinct varieties of rock compose the new red sandstone in the valley of the Connecticut.

1. *Conglomerates*. A conglomerate, composed almost entirely of the ruins of granite and mica slate, forms, in connection with a sandstone of similar character, all the lower beds of this formation; and these two varieties embrace all the rock in Massachusetts and Connecticut, that has usually been denominated *old red sandstone*. The two varieties pass into each other by insensible gradations, and even the finest portion of the sandstone is coarse. The strata are from one to two, and even three or four feet thick; and for the most part, the slaty structure is almost entirely wanting. The prevailing and almost uniform color of the rock is red; and even the imbedded nodules, when not very large or compact, are penetrated with this color. Yet where this rock approaches granite and mica slate, as in Bernardston, Greenfield, Deerfield, Whately, and Southampton, it is somewhat variegated; some portions being of a light gray color; as if a heat so powerful had been applied to it, as partially to expel the iron, or change it from an oxide into some other compound. The nodules of the conglomerate are sometimes one or two feet in diameter; but for the most part, they are only a few inches thick. A variety occurs in Bernardston, Southampton, &c. (Nos. 135, 136,) which can hardly be distinguished in hand specimens from granite; being composed of fragments, but little rounded, of quartz and feldspar; the latter of a flesh color. Sometimes the nodules, as at sugar Loaf, in Deerfield, are graphic granite, which is often quite beautiful; the feldspar being of a lively flesh color.

* Geological Manuel, p. 386.

† System of Geology. Vol. 2, p. 227.

In Greenfield and Bernardston, near the junction of the new red sandstone formation with the argillo-micaceous slate, a conglomerate occurs, composed of argillo-micaceous slate and white quartz. This was obviously derived from the detritus of the slate against which it rests. The general color of this rock is red; and even the mica slate on which it reposes, exhibits the same color several feet from the junction. (Nos. 137 to 139.)

Another variety of conglomerate, which is found only in connection with the upper beds of the new red sandstone, is of a dark, reddish gray color, and is composed of fragments of mica slate, talcose slate, chlorite slate, hornblende slate, and slaty quartz rock, with occasional nodules of quartz, feldspar, and granite. The cement appears to be the same materials comminuted. This is the coarsest conglomerate in the Connecticut valley. It constitutes a considerable part of mount Toby, in Sunderland, where the imbedded nodules are sometimes three or four feet in diameter. It extends through Montague, and at the mouth of Miller's river, as well as on the opposite side of the Connecticut at that place, it may be examined to good advantage. South of Sunderland, I have not found it, except at Durham, in Connecticut. Unless viewed on a large scale, this rock scarcely exhibits any stratification. The strata are sometimes eight or ten feet thick. (Nos. 140 to 143.)

At Turner's falls a much finer and more compact gray conglomerate exhibits itself, composed of the same materials as the last, except that it abounds more in quartz and feldspar. (No. 150.)

A reddish conglomerate, made up of nearly the same materials as that first described, (except that it contains more slate,) abounds among the lowest of the upper beds of this formation. (Nos. 144 to 147.) It is not as coarse as the last variety, and the strata are usually less than a foot thick. It is common in mount Toby and on the east side of mount Holyoke, in Granby.

*Tufaceous conglomerate* is another variety of no small interest. It reposes on the greenstone on the east side of mount Tom and Holyoke; and consists of a mixture of angular and rounded masses of trap and sandstone, with a cement of the same materials. The nodules are sometimes one or two feet in diameter, and the stratification is not very distinct. I do not doubt but the same rock may be found on the east side of nearly all the greenstone ranges in the Connecticut valley. Its thickness is but small, and it graduates on one side into greenstone, and on the other into sandstone. (Nos. 151, 152, and 285.)

2. *Sandstone.* The lowest and most abundant sandstone in this formation has been described with sufficient minuteness, in connection with the conglomerate with which it occurs. It is used somewhat extensively for architectural purposes. (Nos. 154 to 161.)

A sandstone, which, at a little distance resembles that just described, is found among the upper beds of this formation in Longmeadow and Wilbraham; where it is extensively quarried. It differs, however, essentially from the last variety; being composed chiefly of fine siliceous sand, with occasional specks of mica, cemented probably by the red oxide of iron: for its color is almost blood red. Its particles, however, do not cohere strongly; and this forms the only objection to its use in architecture. The extensive quarries in Chatham, Ct. are opened in a somewhat analogous rock; or in a variety closely allied to it. Its strata are thick and rarely exhibit a slaty structure. (Nos. 165, 166.)

Gray sandstone is not uncommon in this formation; but it is found chiefly in the upper part of the series; or rather in the vicinity of trap rocks: as at Turner's falls, and on both sides of Holyoke and Tom. It is made up of coarse gray sand—sometimes of comminuted granite entirely, as on Holyoke—and varies in color from light to dark gray. In some localities, as in Granby, the strata are thick, and the rock is scarcely schistose; it is there used in architecture. In other places, the strata become thinner. On the banks of Westfield river, in West Springfield, I noticed a variety that resembles the grindstones brought from Nova Scotia, though it is harder.

*Gray micaceous sandstone.* When the last variety takes mica into its composition, it becomes more easily divisible into laminæ; and where that mineral abounds, it is very fissile.

Some specimens of this kind, found in the vicinity of trap rocks, can hardly be distinguished, in hand specimens, from mica slate. (Nos. 177, 178, 179.) Gray micaceous sandstone abounds at Turner's Falls, on mount Toby, in South Hadley, in West Springfield, &c.

*Variegated sandstone.* This is composed of alternating laminæ of light and dark red sandstone, usually somewhat micaceous. The layers are not very evenly arranged; so that their edges present rather a fantastic appearance. I have scarcely met with this rock except on the banks of Westfield river, half a mile west of the village of West Springfield; where the characteristics of the New Red Sandstone are more fully developed than any where else in the valley of the Connecticut. The variegated sandstone there forms thick and workable strata. But unfortunately the rocks at that place are now almost entirely concealed by the detritus of the Western Rail Road.

*Brecciated sandstone.* This is composed of fragments of micaceous sandstone, which seem to have been partially fused and then reunited. It is almost as hard as siliceous slate. It is found about a mile east of Turner's falls, on both banks of Connecticut river, forming a stratum some 20 feet wide. The stratification and schistose structure are very obscure: but on the north shore, the layers have evidently been forced upwards, so as to give them somewhat of a spheroidal form. I hence infer that a mass of unstratified rocks, probably greenstone, lies beneath the sandstone at no great depth; and that when this was forced upwards in a melted state, it partially fused the sandstone. (No. 174.)

Red micaceous sandstone is not unfrequently a member of this formation. The grain is usually fine, and indeed, it commonly approaches very near to shale, into which it passes: yet much of it is too coarse and contains too much siliceous matter to be called shale. It is very common along the east side of our greenstone ridges, as at Turner's falls and in West Springfield. It is quite remarkable for being divided into rhomboidal masses, or joints. On the north bank of Westfield river, in West Springfield, this division is remarkably distinct, and the surface of the rock presents an interesting chequered aspect. The same is the case in the northeast part of Greenfield, just below Turner's falls. (Nos. 191, 192.)

3. *Shales.* (Nos. 199 to 204.) Under this term I include all the varieties of argillaceous slate, sometimes called *slate clay*, found in connection with the secondary rocks. And in Massachusetts such slate occurs only as a member of the new red sandstone series: of that formation it constitutes a very important part. Its colors are gray, red, and black; and in hardness it varies from that of tender schistose marls, to a degree of induration approaching that of siliceous slate. The red variety is most abundant: especially in the region of Enfield and Hartford, in Connecticut Sometimes it takes mica and sand into its composition, and then passes into the red micaceous sandstone, as already remarked. When black, it is generally bituminous, as at Sunderland, and at Middletown, Connecticut; where are found upon it the impressions of fish and vegetables. Some of the black colored slate, as at Turner's falls, splits into irregular, somewhat wedged shape pieces; and indeed, easily disintegrates and falls to pieces: when it resembles comminuted coal. It frequently contains sulphuret of iron; which by decomposition, causes the slate to exfoliate: in some places, also, as at Turner's falls, and on Chicopee and Westfield rivers, this shale abounds in nodules of argillaceous iron ore, of a poor quality. Some of the black non-bituminous shale of this formation, has almost lost its slaty structure in the process of induration. Thin pieces of it give a ringing sound when struck. This variety abounds in the vicinity of Turner's falls: as, indeed nearly every other variety does. There we find a gray variety, which is so soft that it may be impressed by the finger nail.

On Westfield river, in West Springfield, both the red and black shales are traversed by numerous veins of satin spar; itself often of a reddish hue. They are rarely more than an inch wide, but often several feet long; and run uniformly across the laminæ of the slate.

In the same place the black shale, as well as the bituminous marlite, and some varieties of slaty

sandstone, contain masses of septaria, or the *Ludus Helmontii.* They vary in size from an inch to 5 or 6 inches in diameter, and are usually flattened or reniform. The envelope appears to be an argillo-ferruginous magnseian limestone; and the cavities are lined, and sometimes filled, by white calcareous spar. The interior is divided into irregular masses, or sometimes into polygonal prisms.

The hypothesis which imputes the cavernous structure of these argillo-calcareous masses to desiccation, and the subsequent filling up to the infiltration of carbonate of lime in a state of solution, seems to me liable to few objections; and, indeed, is quite satisfactory. But I have already given it somewhat in detail, when speaking of columnar argillaceous iron ore.

4. *Limestones.* (Nos. 205 to 216.) When the black bituminous shale, that has been described, takes into its composition enough of calcareous matter to produce effervescence with acids, it becomes *bituminous marlite.* It is not very common in this sandstone formation. Yet one finds it in considerable quantity on the banks of Westfield river, in West Springfield; and I have ascertained that the stratum of slate in Sunderland, which contains the best preserved relics of fish, is bituminous marlite. Although this rock contains but a small proportion of calcareous matter, yet it certainly does not deserve to be described as a distinct rock; and it may be conveniently mentioned under the head of limestones.

Strongly fetid limestone occurs, interstratified with the micaceous sandstones of this formation, at two places in the northwest part of West Springfield. At the most northern locality, I noticed only a single bed above ten feet thick: but two miles south from that spot, several beds, not far apart, may be seen, associated with greenstone, as well as sandstone. The rock at both places is of a dark gray color and nearly compact. Its fetid odor when struck, is exceedingly strong, so as even to produce nausea. It is wrought to some extent for water proof cement. (Nos. 213 to 215.)

At Paine's quarry of fetid limestone in West Springfield, a mass of greenstone comes in contact with, or very near, the limestone: and the consequence is, that a portion of the carbonic acid has been driven off, so that the rock appears to be the genuine tripoli of European writers. Sometimes it is easily crumbled down; and in uncovering the limestone, great quantities have been mixed with the soil and of course ruined, or nearly so. I am inclined to think that the heat has produced some other change besides the mere expulsion of the gas: but I am not prepared to say in what it consists Suffice it to say, that specimens may be found in all states of aggregation, from the unchanged limestone to powder. Nor can I doubt but the proximity of the igneous rock has been the chief cause of the production of the tripoli.

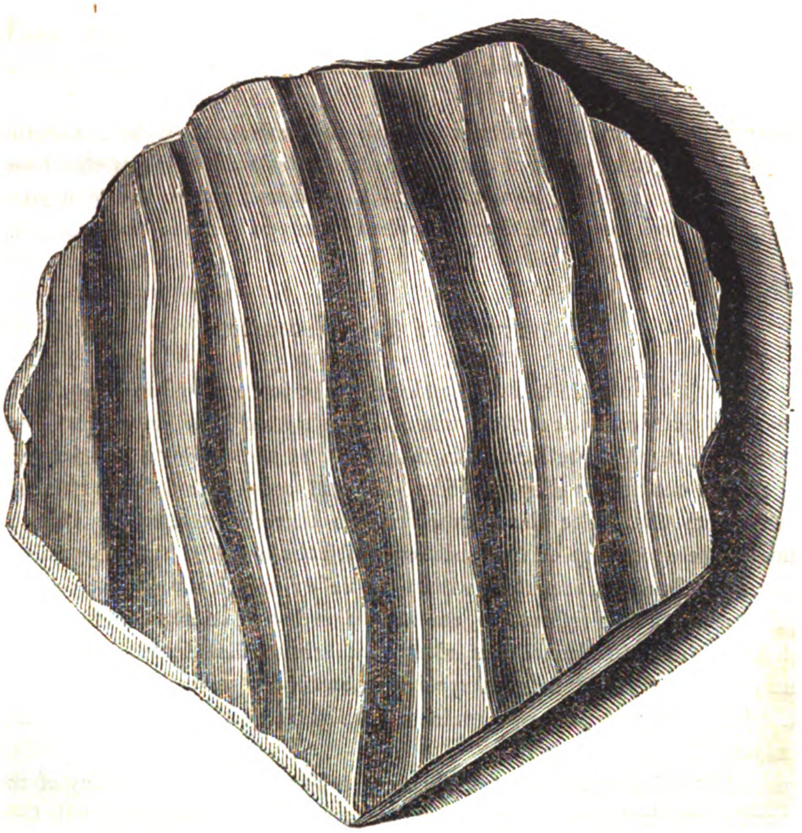
I doubt whether much genuine bituminous limestone exists in the new red sandstone in Massachusetts. Yet when the bituminous marlite takes a large quantity of lime into its composition, it becomes bituminous limestone; and perhaps some of this variety may be found in West Springfield. It is also said to occur in Southington and Middletown, Ct.: and the fetid limestone, also, (all of them connected with the new red sandstone,) in Northford, Ct.

At Turner's falls, on the north shore, I found, a few years ago, a stratum of coarse argillaceous limestone, a foot thick, which was neither bituminous nor fetid: but the subsequent removal of the dam over Connecticut river, has covered the spot beneath the waters.

On the banks of Westfield river, in West Springfield, we find layers of what appears to be an argillo-ferruginous limestone, interstratified with the slate, and only a few inches thick. Where the water has laid bare this rock, it sometimes presents the whole surface divided into small prisms of only a few inches in diameter and length, whose axes are perpendicular to the planes of the strata. They have four or more sides, though irregular, and their sides do not touch. They appear to have resulted from the same cause as the septaria already described; and to be in fact only a variety of septaria. These layers, I am sorry to say are now covered with the detritus of the railroad, except at a spot perhaps 100 rods above Mitineaque Falls.

Upon the finer varieties of this formation, *ripple marks* are very common. In general they so exactly resemble those gentle undulations, common upon the shores of existing rivers and estuaries, that the most determined skepticism cannot resist the evidence of their identity. The ridges and hollows vary in width from one quarter of an inch to at least two inches. At Wethersfield I noticed a singular variety, which is shown on Fig. 88. The principal grooves are more than an inch wide; and the ridges intervening between them, are not rounded as is usual, but steep, so as to become wedge shaped; and their tops form sharp edges. But the most remarkable peculiarity is, that at the bottom and in the middle of the principal furrows, there is a small low ridge, corresponding in direction and general character to the principal ridges. Did these low ridges occur only occasionally, it would not be remarkable. But they regularly alternate with the larger ones, and are almost exactly midway between them. These facts show the agency of some law in their formation. But I am unable to conceive to what peculiarity in the movement of the water, they owe their origin.

Fig. 88.



From this sketch of the lithological characters of this group of rocks, it will be easy to distinguish between the lower beds, which have heretofore been considered as the old red sandstone, and the upper ones, which have been called a coal formation. The lower beds are distinctly

stratified, but rarely slaty; whereas the upper ones are usually so: although some varieties of conglomerate, scarcely exhibit any marks even of stratification. In the lower beds is no shale. Their color is almost uniformly some shade of red: but as already shown, the upper beds are of various colors and shale is abundant.

The greater abundance of granite nodules in the conglomerate of the lower beds of this formation, than in that of the higher, has led some geologists to regard them as belonging to distinct formations. But as a general principle, it will not answer to conclude that conglomerate to be the oldest rock, which contains rounded masses of granite. For a deposit of granite might be so situated, that an abrading current would tear off large quantities of it, while much later rocks might flank its sides in such a manner as to be almost entirely protected from the water. The recomposed rock hence resulting, would, therefore, contain granite nodules chiefly. Whereas it might be that the more recent rock above spoken of, once covered the granite and was worn away by an agency that could not touch the granite. Hence the earlier mechanical rock thus produced would consist chiefly of fragments of the schists. Besides, geologists now generally admit that granite is a later rock than most of the primary ones; and sometimes even of the same age as the highest of the secondary; since there is evidence that it has been protruded through the chalk: and finally, in the present instance, some of the lowest beds of the sandstone under consideration, are composed of fragments of the latest of the primary stratified rocks in the region; as in Bernardston and Greenfield, where the conglomerate is made up chiefly of argillo-micaceous slate.

Extensive ranges of greenstone are connected with the sandstone of the Connecticut valley. But I need spend no time, in the present state of geological science, to show that trap rock cannot be a member of the sandstone formation, and that it was subsequently introduced. Its characters and relative position will be described when I come to speak of the unstratified rocks.

## *Topography of this Formation.*

With a single exception, all the new red sandstone hitherto described in New England, lies in that part of the valley of Connecticut river which extends from New Haven to the north line of Massachusetts: and in this State none is found out of that valley. An inspection of the Map, which marks out this valley, on Fig. 49, will convey a definite idea of the space covered by this formation. For the hills which are there represented as bounding the valley, commence on the outer edge of the sandstone. All the included space is sandstone, excepting those ranges of hills which are drawn within the valley, which are greenstone.

The single exception above referred to, embraces a valley 10 or 12 miles long, extending from Woodbury to Southbury, in Connecticut, along a branch of the Housatonic river. There we find the same varieties of sandstone, accompanied by analogous greenstone, as in the valley of the Connecticut. The two valleys are separated by a high ridge of primary rocks, through which they have no lateral communication.

As the general direction of the strata of the new red sandstone in the valley of the Connecticut is north and south, inclining a few degrees east, and the dip easterly, it will follow that the the lower beds of the group must occupy the western part of that valley. And I have already remarked, that the greenstone ridges generally separate the upper from the lower beds. In Gill, Greenfield, and on Mount Holyoke, however, the observer will see schistose sandstones cropping out beneath the greenstone; though in receding westerly from the greenstone he will find the slaty character of the rock soon to disappear.

In the central parts of the Connecticut valley, from South Hadley nearly to Middletown, the shales and finer sandstones prevail almost exclusively; so that in excavating 15,000 cubic yards

of stone at Enfield Falls, not a pebble as large as an acorn was observed.* The prevailing color of the slate in that region is dull red or chocolate; and being easily decomposed, it imparts a like hue to the soil.

The coarser and the finer beds do not, however, in all cases, occupy separate portions of the valley exclusively; but in many places they are interstratified in almost endless variety. The section laid bare by the Connecticut, for three miles above, and nearly a mile below Turner's Falls, of which a sketch will be given in treating of greenstone, presents a good example for examination. The coarser varieties, however, are not so abundant there, as at Mount Toby in Sunderland. On the west side of Connecticut river, opposite Sunderland, Deerfield mountain exhibits nearly every variety of the lower beds of the formation. Let the observer pass to the east bank of the river, at Whitmore's ferry, three miles north of Sunderland village, and he will land upon a ledge of the coarsest conglomerate that has just been described. Lying directly above this, and dipping a few degrees easterly, as do all the strata of Mount Toby, he will find the black bituminous shale containing impressions of fish, 10 feet thick. Immediately above this, succeeds a coarse conglomerate, scarcely differing from that beneath, and forming a mass 200 or 300 feet thick. Proceeding southeasterly to the top of Toby, not less than 900 feet above the river, he will find numerous alternations of the coarsest conglomerates with the finest red and grey sandstone; or rather shales. And the passage from one variety to the other is not in general gradual, but sudden; so that the line between the finest and coarsest materials is well marked.

It is very obvious, in such cases, that the finer layers of the rock must have been deposited in still waters, and the coarser materials have been the result of powerful abrading currents.

From the nature of the materials composing the different beds, it appears also, either that the currents which collected the detritus, must have come from various directions, so as to pass over different rocks; or in the same channel, different rocks must have been worn through. The latter supposition is probably the true one. There is one other, however, that may be suggested. Where the current was violent, it might have brought detritus from a much greater distance than when more quiet. By the two modes last suggested, we may explain the change of materials, and various degrees of fineness, without supposing any essential alteration in the direction of the stream that collected them together.

## *Dip, Strike, and Thickness of the Strata.*

Although subject to local variation from local causes, yet the general dip and strike of the strata of this formation are quite obvious. The direction is not far from north and south, and the dip easterly, at an angle from 10° to 20°. Fifteen degrees is probably about the medium dip: and the prevailing direction is a few degrees east of north. In particular places, however, the dip is found at all angles, from 0° to 80°. This is remarkably the case in the vicinity of Turner's falls; as may be seen on the section of that place to be given farther on. This extraordinary dip, however, appears to be easily explicable from the proximity of greenstone and granite; as I shall attempt to show when I come to treat of those rocks. Near the eastern extremity of Mount Holyoke, also, these rocks mount up on the ridge of greenstone at an angle of 55° or 60°. Here too the direction of the basset edges is about northeast and southwest. The presence of greenstone in this case, also, as I shall attempt to show, will explain these anomalies. In the west part of Westfield, and near the center of Hatfield, the lower beds of this formation have a dip to the west, of about 10°. The same is also the case in Bernardston. In the north part of

* Mr A. Smith on the Connecticut valley, Am. Jour. Science, Vol. XXII. p. 220.

Hadley, I have observed strata running nearly east and west, and dipping 10° north. The probable presence of granite at no great depth in all these cases, will readily account for these exceptions.

Although the new red sandstone must come in contact with the primary rocks on both borders of the Connecticut valley, yet I have discovered the actual junction only in one spot. Half a mile south of the 'Glen,' or Gorge, in Leyden, near a saw mill, the peculiar conglomerate made up of argillo-micaceous slate and quartz, reposes upon that slate, and has a dip to the south from 20° to 30°; while the slate is nearly perpendicular, and the strike of its edges nearly north and south. Admitting the elevation of the slate subsequent to the deposition of the sandstone, the southern slope of the edges of the former in Leyden, will explain the southern dip of the latter at this place.

The following are the dip and strike of the new red sandstone in several places in Massachusetts, where it does not seem to have been subject to local deviations.

Between West Springfield, and Westfield, along Westfield river, east of the greenstone; direction, north and south; dip, 15° to 20° east.

Mount Tom and Holyoke beneath the greenstone; direction, north and south, inclining several degrees to the east of north, dip 15° to 20° east.

Most northerly lime quarry, West Springfield: direction north and south; dip, 15° east.

Rock Ferry, (S. Hadley, at Titan's Pier); direction, nearly north and south: dip, 20° east.

Sunderland; direction, generally north and south: dip, between 10° and 15° east. At Whitmore's Ferry, however, the stratum containing the ichthyolites, is nearly horizontal; but this is overlaid by sandstone, dipping east from 5° to 10°.

Deerfield; (Sugar Loaf and Deerfield mountain;) direction, north and south; dip, 10° to 15° east.

Do. at Hoyt's quarries, in the west part of the town; dip, 15° to 20° east.

Greenfield; near the village; dip, 20° to 30° east.

N. Wilbraham, east of the village, strike N. and S. dip E.

Longmeadow, E. part; strike N. and S. dip 10° to 20° E.

Other localities might be cited, but it seems unnecessary. It ought, however to be mentioned, that as we go south into Connecticut, where the breadth of this formation increases, we find the dip to decrease; so as in many places to be almost nothing. In the vicinity of unstratified rocks, however, it presents much irregularity.

## *Mineral Contents.*

*Coal and Copper.* These are the two most important minerals in an economical point of view, hitherto found in the new red sandstone. But I have given so full an account of them in the first part of my Report, that little more need be added here. All the veins of copper there described, run nearly north and south; indicating some common cause from which they originated. That on one of the islands in Turner's Falls, has a westerly dip of about 45°; while the strata of sandstone dip easterly at the same angle. Around this small vein, on the edges of the sandstone strata, I noticed numerous lenticular crystalizations of carbonate of iron. (No 240.)

*Lead, Zinc, and Iron.* At Paine's quarry of fetid limestone in West Springfield, I noticed small quantities of galena; and at Meachem's quarry, a little north of Paine's, I saw blende. Nodular limonite is sometimes found in the shale at South Hadley Canal, Turner's Falls, &c; but in too small quantities to be of any importance.

*Iron Sand.* Bushels of this substance, highly magnetic, may sometimes be collected on the Montague shore of Connecticut river, 40 rods below Turner's falls. Probably it proceeds from the disintegration of the new red sandstone at the falls. Some of the iron-colored grains are not magnetic enough to be taken up by the magnet and resemble iserine. It is also very common to meet with iron sand on the shores of the Connecticut in Hadley, where I have collected large quantities. I am not sure however, whether this as well as that in Montague, does not originate from the diluvium, and not from the red sandstone.

*Sulphate of Baryta.* This mineral, accompanies the veins of copper ore in the new red sandstone in most instances, both in Massachusetts and Connecticut. In this State, it is most abundant at the copper veins in Greenfield; where it forms veins from six to eight inches wide.

*Fibrous Limestone, or Satin Spar.* The red and black shales, on the banks of Westfield river, in West Springfield, contain numerous veins of this substance from an inch to a mere line wide. Sometimes it forms a thin seam between the layers of slate. The same mineral occurs along with the fish impressions at Sunderland. Common calcareous spar exists in these rocks as well as satin spar; and Prof. Shepard says also, that the ankerite occurs here.

Stalactical concreted carbonate of lime is frequently found in this formation. At West Springfield I found it an inch or two thick between the layers of sandstone, near the southern bed of fetid limestone. At the Sunderland cave, it forms small and imperfect stalactites on the coarse conglomerate: and on the same conglomerate, on the east side of mount Toby in Leverett, I found a large quantity of it coating over a perpendicular wall several inches thick. (Nos. 226 to 230.) This had obviously been derived from the conglomerate by water; and it shows that carbonate of lime is more frequent in this formation than one would be led to suspect from its general appearance.

*Sulphate of Lime, etc.* Rev. E. Davis, states that this interesting mineral exists in small quantity on the banks of Westfield river, in West Springfield. I have found it also, in the form of selenite, on gray sand stone at South Hadley Canal, in quite small quantity. These facts are sufficient to encourage farther research after so valuable a substance.

In some of the seams of the fetid limestone at West Springfield, I have noticed thin layers of purple fluate of lime.

It ought not to be forgotten, that in Europe, the new red sandstone group is one of the depositories of salt and gypsum, as well as the rich mines of mercury in Carniola; nor ought it to be supposed that our new red sand stone has been examined thoroughly enough, to render it certain that the same minerals do not exist here.

It is now also pretty well ascertained, that the diamond mines of Golconda and Panna in India, and those in South America, occur in a conglomerate belonging to the new red sandstone.*

And when we consider how easily one might overlook so rare a substance as diamond, observers, I should hope, will recollect this fact in their future examinations of this rock in Massachusetts.

## *Organic Remains.*

Though the amount of organic remains found in the new red sandstone be quite small, and though I am much perplexed in regard to the specific nature of many of them, still a few of them possess a very great interest,

* Conybeare's Report on Geology, (1832,) p. 395 and 398.

and will need great minuteness of description. They belong to the two great classes of organic nature; viz. Vegetables and Animals.

### I. VEGETABLE REMAINS.

Perhaps the most common form in which vegetable relics occur in this formation, is in broken fragments, rarely more than a foot or two long, and generally not more than one or two inches, but sometimes six inches wide. These are sometimes branched and consist of a thin layer of coal. They exhibit no striae of importance, nor joints; and I am inclined to regard them as the fragments of dicotyledonous plants—probably terrestrial—that have been drifted into their present position by currents. Certainly they very much resemble fragments of existing vegetables, which now occur in the bottoms of rivers and estuaries. The localities where I have noticed them, are on the large Island at Turner's Falls, at the locality of ichthyolites in Sunderland, on Agawam river in West Springfield, and especially at a locality of fossil footmarks, to be hereafter described, in the southeast part of Northampton, on the banks of Connecticut river. At the latter place, some square rods may be seen almost covered by these fragments. In most of the localities the rock is a rather coarse micaceous sandstone.

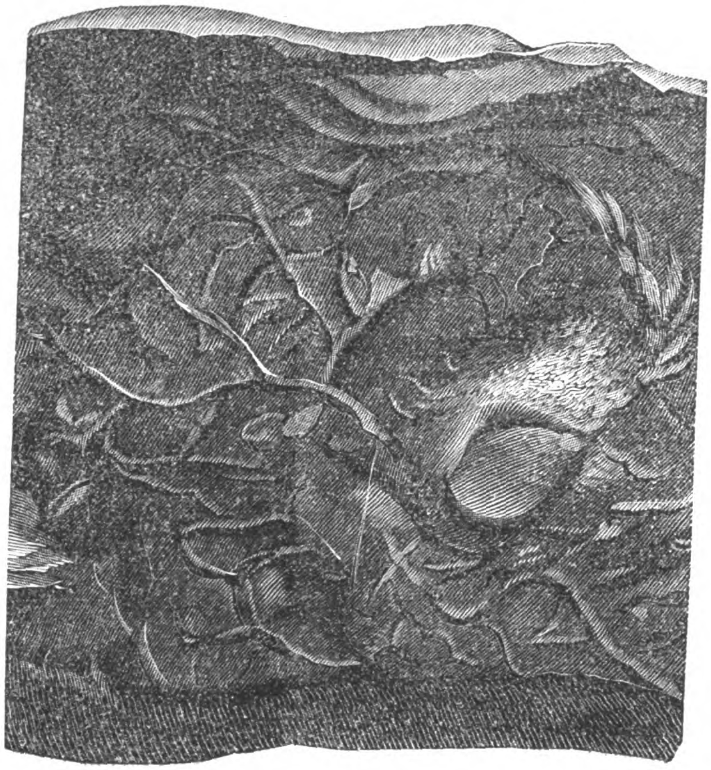
In some instances these relics appear to be flattened stems, whose surface is covered by carbonaceous matter, and the central parts are occupied by siliceous matter, not differing from the sandstone, or shale, in which they occur. Often the layer of coal is quite irregular, as if it penetrated the stem, as well as to enclose it. Sometimes also the internal axis or heart of the vegetable, is visible.

Another set of organic remains in this sandstone I have been inclined to refer to marine plants: some of them, perhaps, to fucoides. In general little more than the impression of these remains is left upon the rock, without any carbonaceous matter. Sometimes, however, a flattened stem occurs, which will separate from the rest of the rock; but is of the same composition, except some difference of color at the surface. These stems are rarely more than an inch in diameter; but they are often 6 or 8 feet in length; and retain their size throughout. They rarely lie on a right line in the rocks, as a solid stem of a dicotyledcnous plant would do; but in a serpentine direction; such, for instance, as the flexible foot stalk of a large Ulva would be apt to assume.

Plate 29 Fig. 1, exhibits a plant sometimes met with on the red shale of this formation. It is little more than an impression. But I fancy that the margin shows the small vesicles of a fucoid. This specimen was obtained at the Cove in Wethersfield in Connecticut.

Fig. 89, exhibits a specimen very common on the hard black shale of Cabotville and Chicopee. It resembles exceedingly a species of living Lemania, which now grows on the rocks at the bottom of Connecticut river, and I have little doubt but it is allied to that genus. The drawing cannot exhibit its minuter characters well.

Fig. 89.



I have met with specimens of Plate 29, Fig. 2, at the ichthyolite locality in Sunderland, and at the bridge over Connecticut river in Enfield, Ct. It resembles somewhat the rachis of a dicotyledonous plant. Possibly it may be a Voltzia.

On the hard gray sandstone at the Cove in Wethersfield, is sometimes an appearance in relief, resembling very large and long leaves of the living Aloe. I saw one specimen which seemed to be a flattened relic of this sort, six inches across at its base, and 4 or 5 feet long. Usually they are not more than two inches wide, and perhaps two feet long. They rapidly enlarge near the base, doubling their diameter in the space of a few inches. They taper upward, also, quite fast, and come nearly or quite to a point. They do not appear to have been perfectly cylindrical; if I can judge from the deep longitudinal furrows which they sometimes show on their surface. There is no carbonaceous matter remaining; but the whole is changed into sandstone.

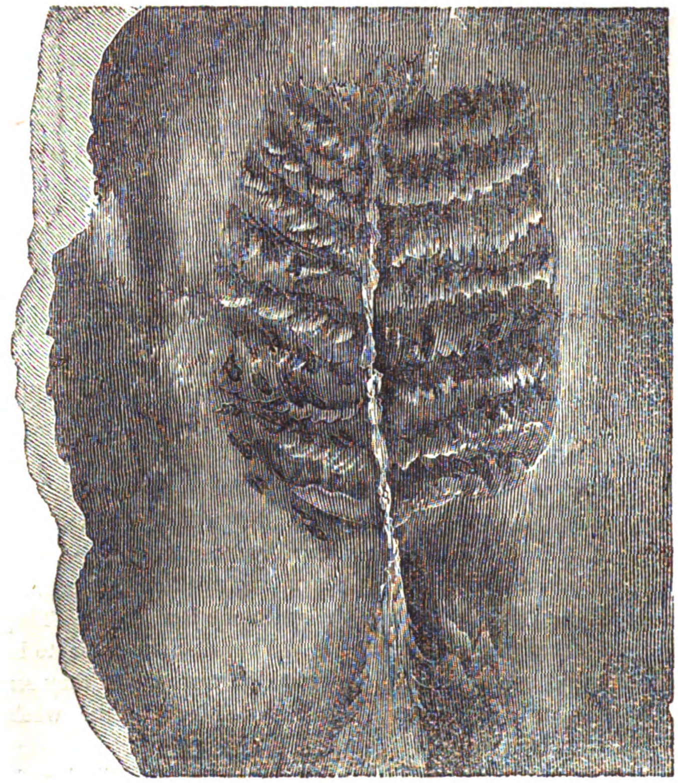
Frequently, but not always, connected with the relics just described, and spread over the stone all around them, are numerous spine shaped small bodies, entirely converted into stone. They are sometimes two or three inches long, and are not usually simple: but similar spines proceed from opposite sides, though shorter and blunter than the central one. They commonly lie nearly parallel to one another, with their points in the same direction. It seems difficult to avoid the conclusion, that they are the leaves of some peculiar plant, and probably of that described in the preceeding paragraph. Plate 29, Fig. 3, shows a surface of a few inches on a specimen from the Cove in Wethersfield; which is the only locality where I have noticed this very distinct relic.

From the same place I have a specimen of fine red sandstone, containing an impression, which

I have endeavored to represent on Plate 29, Fig. 4. The surface of the rock, has been considerably acted upon by the weather: but there is a distinct appearance, as if several feathers had left the impression of their fibres on the stone: and if I do not mistake, they proceed from the rounded termination of some plant; although this is not well defined: somewhat like the leaves upon the terminal branches of the Lepidodendron. I have never met with another specimen.

Fig. 90, shows a peculiar vegetable relic which has the general appearance of a fern. But the rock on which it occurs is a coarse grey sandstone; and the only specimen I have been able to obtain, had long been weathered; so that if the delicate leaflets of the frond of a fern did once exist upon it, they cannot be now traced. All that can with certainty be traced, is a principal axis, from which frequent and exactly opposite branches proceed, more than an inch long. This specimen was taken from a quarry in Montague; 100 rods northwest of the bridge over Connecticut river, leading to Greenfield. I was told that such relics are not very unfrequent there: but I have tried in vain to obtain a fresher specimen.

Fig. 90.

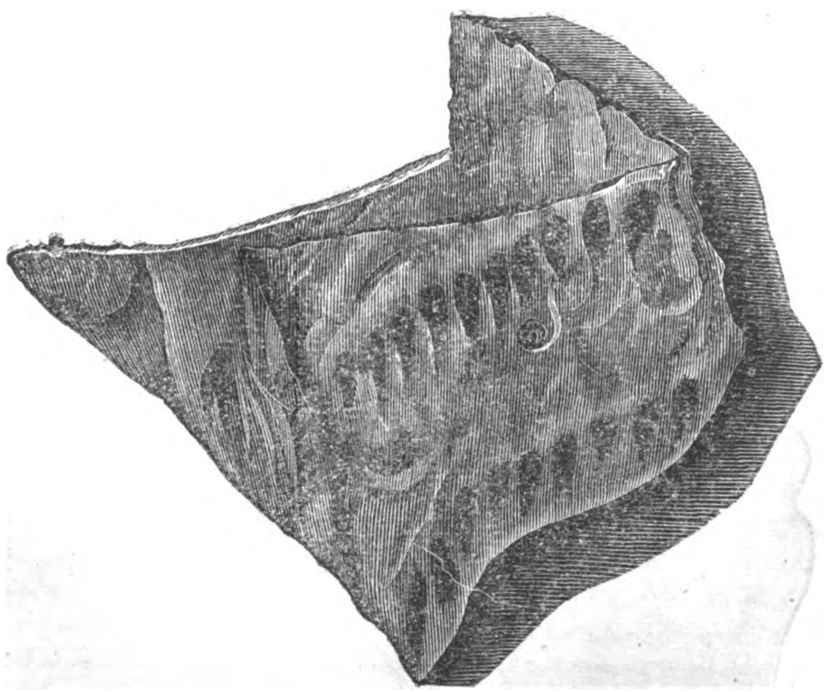


The original from which Fig. 5, Plate 29, was sketched, was found at the Falls in South Hadley, among the fragments thrown out in excavating the Canal; and it is not very uncommon there. The drawing conveys but a poor idea of the specimen; because it does not show a great number of exceedingly minute fibres, corresponding in their general direction to the larger ones. I have sometimes suspected that the impressions may have been that of some large thin membrane of a marine vegetable, full of some sort of vessels, or veins. But I rather incline to the belief, that it may have resulted from a great number of such specimens as I have already exhibited on Plate 29 Fig. 1: for some of the larger veins on Fig. 5, appear to be margined by such an appearance as fig. 1 exhibits.

On Fig. 91, is an appearance not uncommon on the fine red shale at Middletown and Enfield in Connecticut. Generally there is no appearance as if any body of much thickness had been enclosed; but a few slightly elevated ridges, a little resembling the ribs of a small animal, appear upon the slate, and that is all. Yet in one specimen, which I obtained from the quarry in Suffield, near Enfield Bridge, a protuberance, more than an inch high, 3 inches across, and 6 or 8 inches long, appears with several singular projections on one side. This I have attempted to show on fig. 92. The resemblance of the singular appendages on the left hand margin of this specimen, to those on fig. 91, has led me to place them together. As the specimen was removed from the quarry before I saw it, I cannot say whether the protuberance was on the upper or under side of the stone, as it lay in its natural position.

I have little doubt but both these specimens are fucoids: or rather a part of the frond of an Algae. For the resemblance of Fig. 92 to the *Fucoides Selaginoides and Lycopodioides* cf Adolph Brongniart, *(Histoire des Vegetaux Fossiles, Livraison* 1. Pl. 9, *fig.* 2 *and* 3,) is so striking, that I am almost persuaded to propose for it, as it is obviously a new species, the name of *Fucoides Connecticutensis*. It is well known that analogous sea weeds (as *Macrocystis pyrifera,)* have vesicles filled with air at the base of each leaf. And if we suppose the plant on Fig. 92, to have had a large vesicle at its base, when it was buried in the mud, it might have made an impression before the escape of the air: But when, as it decayed, the air escaped, the envelope would settle into the cavity, so as to give the impression in the rock, such as is described above. Numerous small leaves, like those shown on the edge of Fig. 92, were scattered over the surface of the stone, but insulated.

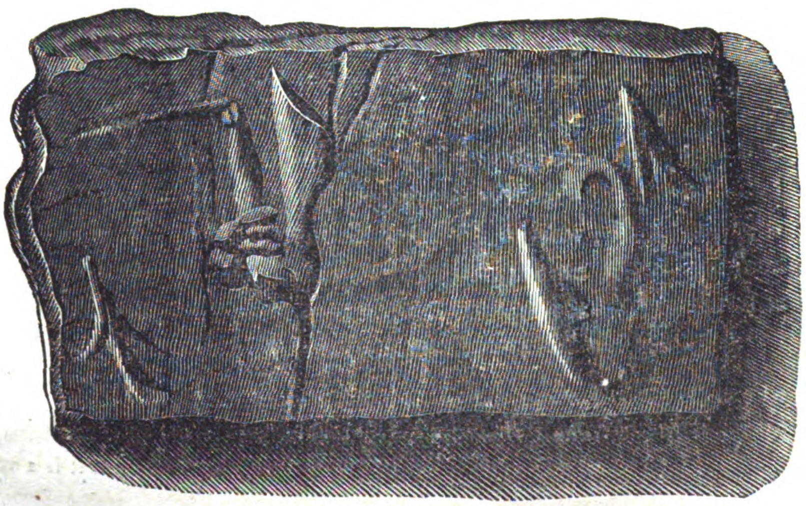
Fig. 91.



On Fig. 93, is shown a specimen that occurs on the dark hard shale of Chicopee river at Chicopee Factory Village in Springfield. Often it has a bifid, and sometimes a trifid division, and the surface has the granulated aspect of an organic relic. I have little doubt but it is a vegetable: perhaps a fucoid.

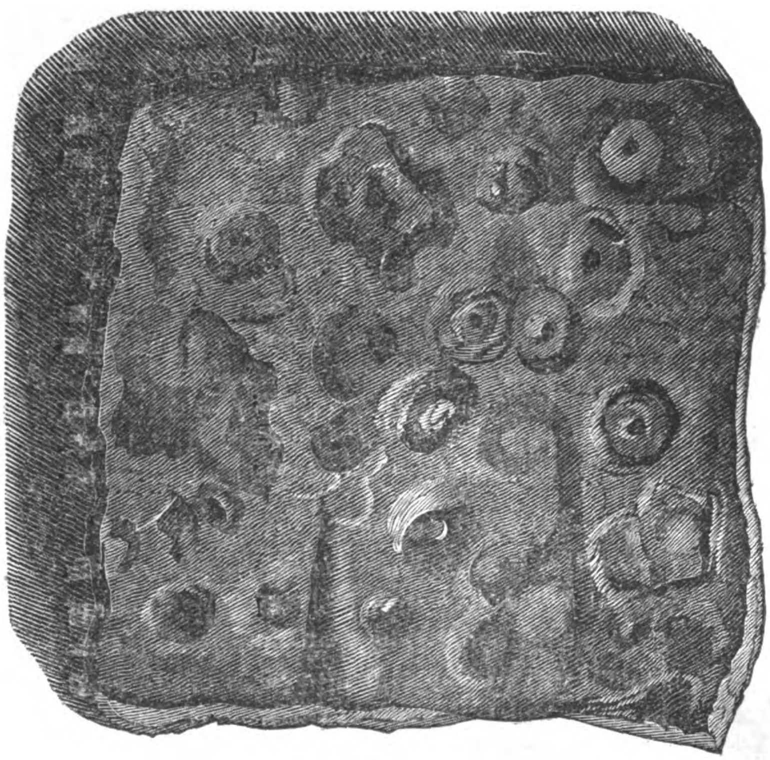
Fig. 92.

Fig 93.



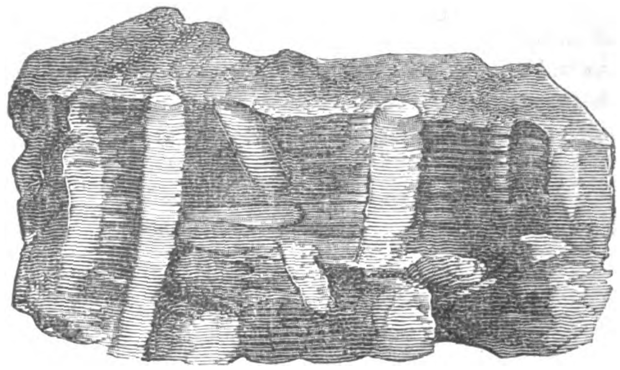
On the shale at the locality of fossil fish in Sunderland, occurs a specimen of which some idea may be formed from Fig. 94. The layers of the rock are penetrated perpendicularly by cylinders, from a quarter to half an inch in diameter, scarcely differing from the rest of the rock, except in being more ferruginous and softer at the center, which is frequently perforated by a very minute hole, running through the specimen. These relics a good deal resemble those peculiar concretions that have been described as occurring in diluvial clay, and some of which are figured on Plate 18, figs. 1 to 9.

Fig. 94.



In the lower beds of the new red sandstone in Deerfield and Greenfield, occurs a peculiar relic, which I figured and described in my former Report, under the name of *Fucoides Shepardi*. In regarding it as a fucoid, I followed the opinion of Dr. Morton of Philadelphia. Dr. Harlan afterwards contested this opinion with much force; and as I have obtained no new light on the subject, I confess myself exceedingly undecided as to the real character of this relic. All I shall do, therefore, is to repeat the description given of it in my former Report. I have failed of obtaining in season for this report, the opinion of a distinguished foreign fossil botanist, which I should esteem of great value in a case where able naturalists of our own country disagree, and which I confess myself unable to decide. Fig. 95, will give some idea of these remains.

Fig. 95.



This relic varies in size from one tenth of an inch to an inch in diameter. More commonly it runs through the rock in a direction corresponding to that of the laminæ; in which case it is considerably flattened. Sometimes it passes obliquely through the layers, and very commonly crosses them at right angles; in which last case it has a cylindrical form. It is rare to see a specimen of any considerable length, that is not more or less curved; and I have never met with one that was branched at all. I have noticed specimens a foot or more in length, and they may be much longer than this, since I have not met with any large mass of rock containing them. The sandstone in which they are found is rather fine and quite soft, and easily disintegrates. They occur near Hoyt's quarries, one mile west of the village of Deerfield; and also a few rods south of the County jail in Greenfield, close by the stage road, and on the road to Bernardston a mile north of the village of Greenfield.

The vegetable matter in these remains is wholly replaced by sandstone. By breaking the specimens transversely a curious structure is revealed. It may be described, by saying that the cylinder is made up of convex layers of sandstone, piled upon one another: and I observe that in the same rock all the specimens have the convex sides of these layers in the same direction; so that on one side of the rock you will see numerous button-like protuberances, and on the other side corresponding concavities. (No. 258.) But I do not know which side is uppermost in the rock, in situ.

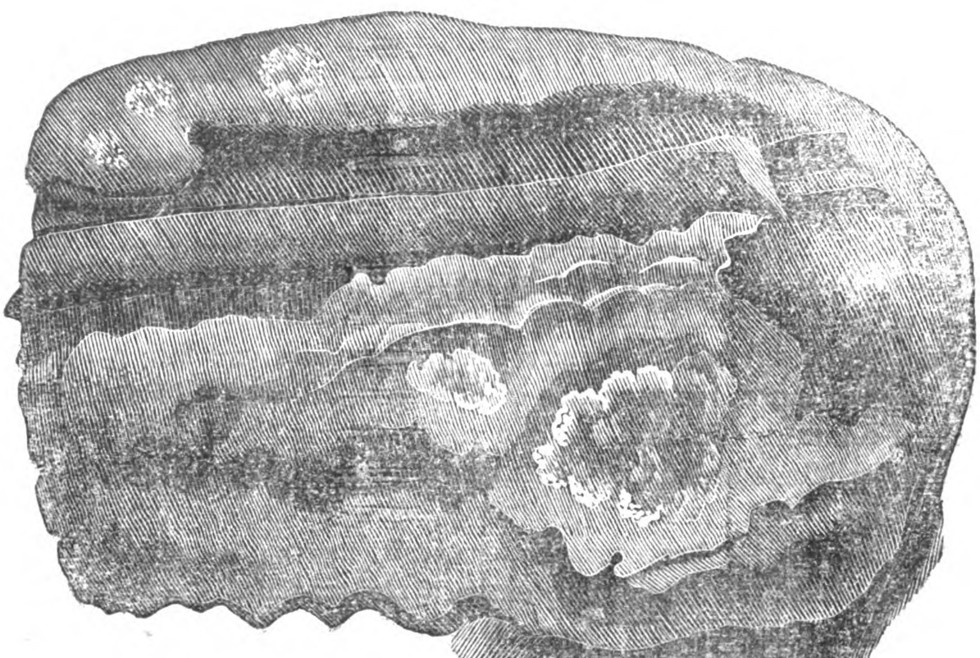
*Fossil Trunk of a Tree.*

I saw this interesting relic several years ago, in Dr. Smith's collection in Southbury, Ct. It was obtained in that place in the sandstone formation extending from Woodbury to the Housatonic; which, although separated topographically from the new red sandstone of the Connecticut valley, appears to possess precisely the same characters. The specimen to which I

refer was cylindrical, eight or ten inches in diameter, highly siliceous, and exhibited the bark very distinctly; which if I do not misrecollect, was carbonaceous. It was discovered in a swamp, and a laborer, mistaking it for a stump of a recent tree, struck it with his axe; and being vexed at the injury his instrument received, he in revenge broke it almost to pieces. The unbroken fragment in Dr. Smith's possession, however, was several inches long.

I shall here describe an unique specimen of vegetable remains, although it does in fact occur in trap rock. But I suppose the trap to have been originally sandstone, which has become trap by partial or entire fusion. It differs from the common greenstone of the Connecticut valley chiefly by being more argillaceous. Yet it has the hardness of greenstone, abounds even more in crystals of feldspar, and contains prehnite and other minerals usually found in the greenstone. It forms beds of considerable thickness on the eastern or upper side of the greenstone, where this rock is overlaid by sandstone, or rather shale. It is in bowlders of this rock in Amherst that I frequently find what must be regarded as vegetable remains. They consist of cylinders of stone, sometimes a little flattened, and often two inches in diameter, running through the specimen. Fig. 96, shows a specimen of this sort which is 24 inches long. In other parts of the same specimen were two other stems of nearly the same size and appearance. One half of this bowlder, I have deposited in the State Collection, the other half in the Cabinet of Amherst College.

Fig. 96.



These cylinders resemble the stems of plants, found frequently in the coal and other formations, except that they show no appearance of bark or organic structure: for *they are in fact converted into vesicular amygdaloid*, the cavities of which are empty. They hence resemble vesicular

lava: and yet their cylindrical form is preserved. None of the surrounding rock is amygdaloidal or vesicular. They can be separated without difficulty from the matrix.

It ought to be mentioned that these cylinders are largest at one extremity and gradually taper to the other; and this fact, with their strong resemblance to silicified stems, and their parallel position in the rock, and I may add, my entire inability to explain them in any other way, have produced the decided conviction that they had a vegetable origin. I suppose they at first became enveloped in sandstone into which they were converted, as is common. Then this sandstone was subjected to so strong a heat as to change its structure and nearly obliterate the lines of stratification, (for these are not entirely gone,) and also to change the siliceous stems into amygdaloid: but yet the heat was not quite strong enough to destroy the form of the stem, as would have been done had the rock become entirely fluid. That matter may change its internal structure without complete igneous fluidity, seems now to be a well established fact. The reason why the stems became vesicular, while the rock around is not so, is probably because the former contained matter easily converted into gas, while the latter did not.

The facts which I have detailed respecting these specimens are very remarkable, and so far as I know, unique in geology. If any doubt my exposition of the case, the specimens will speak for themselves, and must be regarded as curious examples of metamorphic operations in nature.

### II. ANIMAL REMAINS.

The bones of a vertebral animal, several feet long, have been found in two or three places in Connecticut, in the red sandstone. But for reasons that will appear in the sequel, I defer a particular description of them till I come to speak of the fossil footmarks in the same formation.

The most important animal remains in this rock are those of fish. I have already stated that these have been found at several places in Connecticut, and at Sunderland, Deerfield and West Springfield, in Massachusetts. Sunderland, however, at the place called Whitmore's Ferry, is the only locality in Massachusetts where specimens can be procured.

The shale there forms the bank of the river several feet high: but the ichthyolites are most abundant in the lower part of the bed, which corresponds nearly with low water mark. I have dug out hundreds of specimens at this spot; though perfect ones are very rare to be obtained. On one layer of the rock, fifteen inches by three feet, seven distinct impressions were visible. Indeed, I have not unfrequently met with one fish lying across another, without the intervention of a layer of shale: and from these specimens, I can easily conceive how the mistake should have been made, that among the Monte Bolca ichthyolites, one fish was found in the act of swallowing another!

A thin layer of carbonaceous matter usually marks out the spot where the fish lay; except the head, whose outlines are rendered visible only by irregular ridges and furrows. In some cases, however, satin spar forms a thin layer over the carbonaceous matter, and being of a light gray color, it gives to the specimens an aspect extremely like that of a fish just taken from the water.

We sometimes find the specimens a good deal mutilated; so much so, indeed, that the form of the fish is entirely lost: and the scales and fins are

scattered about promiscuously: and this too in the vicinity of other specimens that are entire. Hence we cannot impute this mutilation, as is usually done, to a disturbing force acting on the rock at the time in which the fish was enveloped, or afterwards. But if we suppose that the fish, as they died, were gradually enveloped by mud, it is easy to conceive how some of them might have putrified and fallen to pieces, before they were buried deep enough to be preserved: or it might be that the fish were mostly devoured by some other animal; and in either of these ways, we might expect to find only scattered relics enveloped in the rock.

Enough perhaps has already been said respecting the general character of these fishes. They belong to races, of which there have been left as their living representatives on the globe, only two genera and about seven species: viz. the Lepidosteus, or bony pike of this country, and the Polypterus of the Nile and Senegal: although 17 genera have been found fossil. Professor Agassiz, so justly distinguished for his knowledge of fossil fishes, has given some account of the Sunderland species, partly from the imperfect drawings which I gave in my Report. The tails especially, being quite obscure upon the specimens, the artist was not careful to exhibit them as they undoubtedly ought to be, viz. heterocercal. Plate XIV, Fig. 46, of my Report of 1835, Agassiz names *Palœoniscus fultus:* which, he says, is distinguished "by the large *osselets,* which extend upon the anterior borders of all the fins." This is a rare species; and I have been unable to procure a specimen for the State collection.

Another specimen sketched on Plate XIV, figs. 45 and 48 of my Report, M. Agassiz has named *Eurynotus tenuiceps:* the specific name being given because "the breadth of its head is small in proportion to its length, and to the breadth of the trunk." A much more accurate sketch of this species is given on Plate 29, Fig. 1, of the present Report. In Agassiz's description of the genus Eurynotus, he makes the anterior rays of the dorsal fin large; whereas, in my figure, both in the present and former Reports, the posterior rays are by far the longest. Agassiz supposes a mistake in the drawing: but nearly all the fish at the Sunderland locality belong to this species: and this character of the dorsal fin is constant in all the specimens which I have seen. Perhaps this peculiarity will form the foundation of a new genus: though Agassiz remarks, that "aside from this character, it appears to him, that this fish ought to enter the genus Eurynotus: since its anal is narrow, and it belongs to the section of *heterocercal Lepidoides,*"

I have given the sketch Fig. 2, Plate 29, because it appears to me probable that it may be another species of the same genus as the above. It is much less chubby and the fins are more delicate than the E. tenuiceps. It occurs at Sunderland.

I had drawn another specimen from the same locality, which is a foot long, and the scales

three times as large as those on the species above described: But it is so much mutilated that I have withheld it from the lithographer: especially as I have found but one specimen.

I have sometimes found specimens much less chubby than either of the specimens shown on Plate 29; and considerably longer: but the fins are so deficient, that probably even their genus cannot be determined except by the most practised eye.

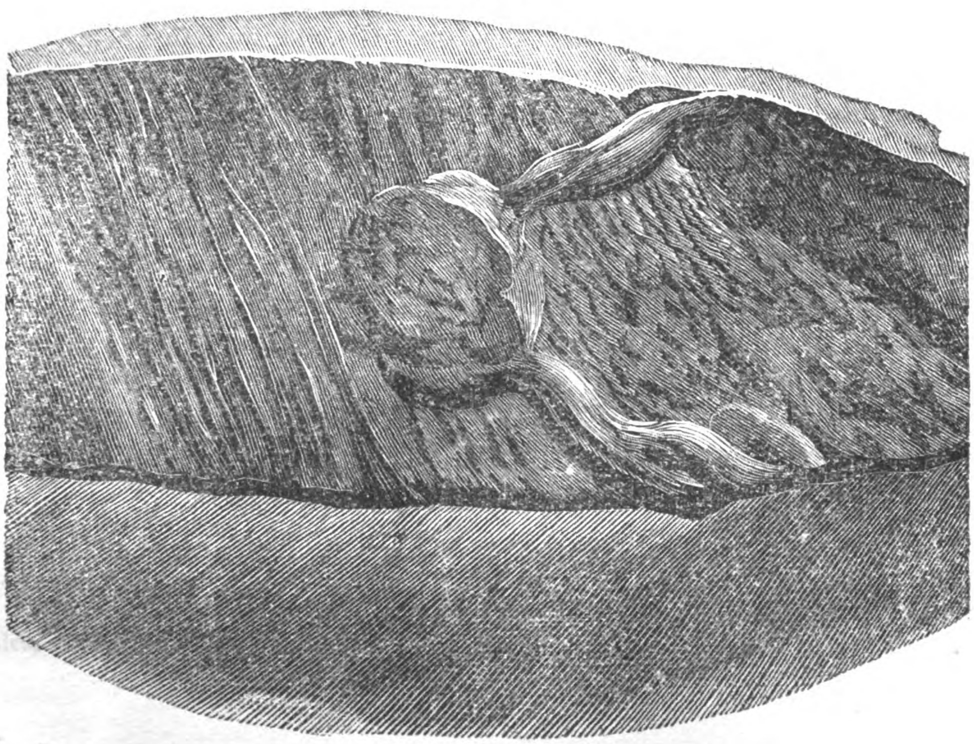
I have met with a single specimen of a much smaller fish at the same locality, and fig. 3, Plate 29, is an attempt to represent it. But the markings on it are so delicate, that it is very difficult I find for an artist to represent it accurately. Besides, the fish appears to me not to lie exactly upon its side. For the delicate rays of the dorsal fin extend over the body a considerable distance. I pretend not to pronounce upon its generic or specific character.

Mr. John H. Redfield, in his account of the fossil fishes of Connecticut and Massachusetts, in the fourth volume of the Annals of the New York Lyceum, has described a new genus from Middletown, under the name of *Catopterus gracilis*. He also describes a new species of *Palæoniscus*, under the specific name of *latus*. Before the publication of this report, I had hoped the final opinion of M. Agassiz would be obtained upon the fishes of this valley, after he had seen specimens of nearly all the species sent to him by Mr. Redfield. But that gentleman has not, I believe, yet received a return.

A quarryman at Chicopee Falls in Springfield, presented me with a single tooth of the family of fishes called Pycnodonts, which he declared he found imbedded in the sandstone of that place. It is not in the least changed; and the shining white enamel still remains. But in other respects it exactly resembles the *Bufonites* of the oolite in England. After seeing how little changed were the fossil bones found in this sandstone in East Windsor, (of which an account will soon be given,) I can easily believe that a tooth might be preserved as perfectly as the one under consideration: nor can I conceive of any inducement on the part of the quarryman to deceive me, as he refused all compensation.

A few relics of a doubtful character will now receive a short description.

Fig. 97.



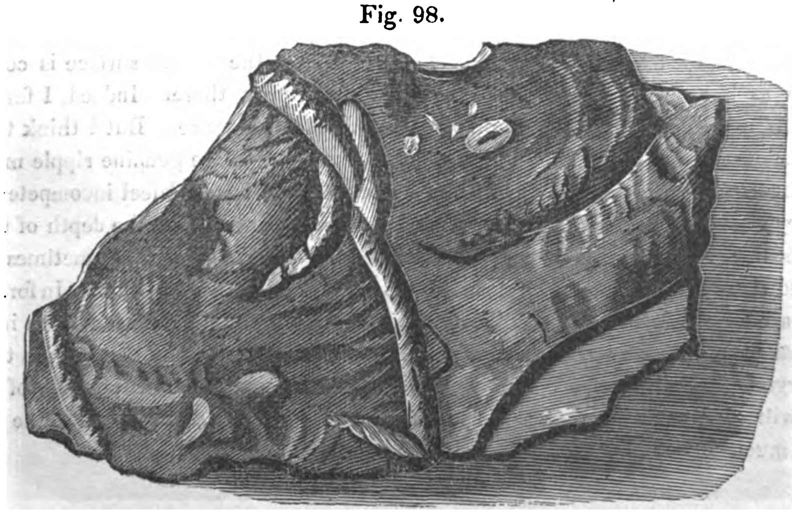
Connected with some of the vegetable remains on the reddish slate of Wethersfield in Connecticut, I have met with spherical bodies, sometimes more than an inch in diameter, to which are attached occasionally bodies resembling the spines of Echini. Fig. 97, represents one of these. No animal or vegetable matter apparently remains; and it is possible that it may be the fruit of the vegetable with which I have found it connected. But it certainly resembles a species of the family Echini.

A variety of remains, not unfrequently met with on the shale of Springfield and West Springfield, as well as at Wethersfield, is shown on Fig. 98. The appearance of a single specimen, is that of a fleshy worm, from a quarter to half an inch in diameter, and two or three inches long. In some cases there is an appearance, especially if the specimen be weathered, of an annulated structure. When several specimens lie crossing one another, as is frequently the case, they are often folded upon one another, just as a mass of soft worms, or intestines, would do; and I cannot doubt but they were originally soft bodies; and yet it is remarkable that they are preserved almost without shrinking. I have sometimes seen the excrements of birds, lapping over one another in the manner above described; and moreover, presenting a somewhat similar ribbed appearance: and after having seen numerous fossil footmarks in the same rocks, which seem to have been those of birds, I was led to suspect that these remains might be coprolites. I therefore attempted their analysis; and although the result does not prove them coprolites, I think it does show that they are animal remains. The substance of these relics is apparently entirely an indurated somewhat concretionary clay. In 100 parts I find the following ingredients.

| | |
|---|---|
| Silica, | 40.85 |
| Subphosphate of Alumina, | 37.00 |
| Alumina, | 1.54 |
| Peroxide of Iron, | 8.48 |
| Phosphate of Lime, | 3.62 |
| Lime, | 3.32 |
| Water, | 2.85 |
| Loss, | 2.34 |
| Uric Acid, a trace? | |
| | 100.00 |

The composition of this substance is so remarkable, that I should be glad to verify it still further by a greater number of trials. But time will not permit. It seems, however, hardly possible to doubt that it had an animal origin.

Fig. 98.

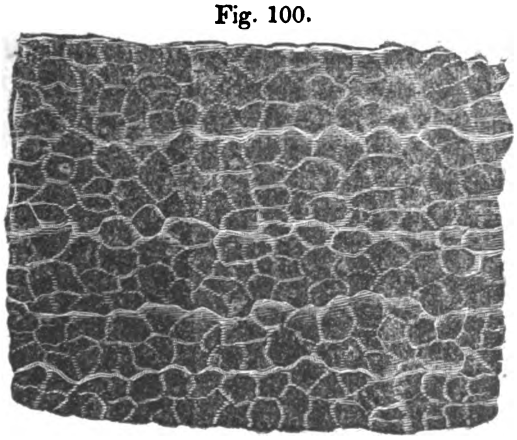


Somewhat analogous to what has just been described, is a specimen represented on Fig. 99, from the locality of fossil fish in Sunderland. I found several square feet of the shale covered with it. It differs from the last chiefly in the much greater taper of the extremities. The specimens rarely cross one another. They have made an impression, both on the shale above and below; which proves that they were solid bodies, enveloped in the matter composing the rock.

Fig. 99.

Half a mile west of Mitineaque Falls in West Springfield, on the north shore of Agawam river, there exists an impression on the shale, which, upon a general view, bears a strong resemblance to fine ripple marks. But upon closer inspection, the whole surface is covered with reticulations, as if an enormous gorgonia had left its imprint there. Indeed, I formerly supposed that this might have been the origin of this curious appearance. But I think that opinion must be abandoned. I cannot doubt but the grooves and ridges are genuine ripple marks. But how the reticulations, which cover the entire surface, were produced, I feel incompetent to determine. They are polygonal, somewhat like columnar clay iron ore. But the depth of the grooves that form them is scarcely more than the thickness of writing paper. Sometimes the part in relief is solid throughout: but sometimes it forms a ring around a depression. In form, the protuberances are a good deal irregular. Towards one extremity of the spot laid open in the shale, the reticulations are much smaller; and it was this circumstance chiefly that led me to suppose it might be organic. I now suppose it may be the result of concretion or possibly of rain drops. Fig. 100, will give some idea of this specimen; but Nos. 264, 265, in the State Collection, will give a much better idea of it.

Fig. 100.



In the fetid limestone of West Springfield there occur some singular bodies, which approach in their structure so nearly to some of the family of Crinoideans, that I was formerly inclined to refer them to an organic origin. Frequently they consist of spherical or hemispherical heads, covered with small protuberances, and terminating below by small cylindrical stems, extending downwards several inches, which certainly bear no slight resemblance to the head and arms of an encrinite. But the discovery of the singular concretions on the floor of a limestone cavern in Lanesborough, which are shown in Plate 18, Figs. 10 and 11, and which have been already described, led me at once to abandon the idea of their organic origin and to refer them to the same cause, viz. concretion. The resemblance of the heads of the cavern deposits, to those in the fetid limestone, was too striking to be overlooked. Figs. 101, 102, will give an idea of the upper part of two of these concretions, and Fig. 103, of the cylinders proceeding from them. By comparing these with Plate 18, Figs. 10 and 11, the resemblance will be obvious; but still more so, by comparing Nos. 268 to 277, with Nos. 2504 and 2505, in the State Collection.

Fig. 101.

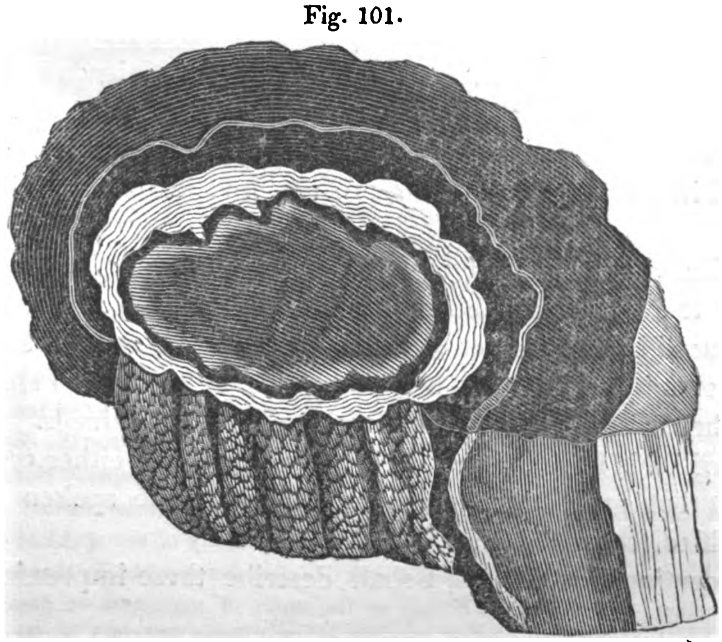


Fig. 102.

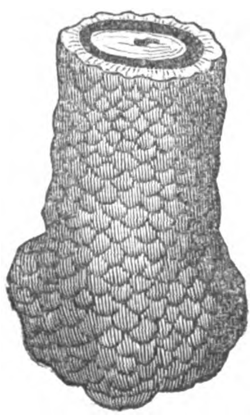
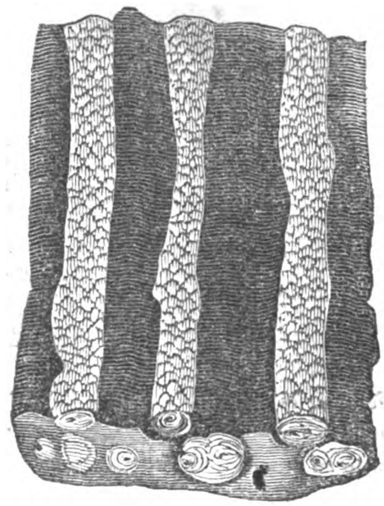


Fig. 103.



### III. FOSSIL FOOTMARKS.

The impressions which I have now to describe, under the name of fossil footmarks, are by far the most interesting relics of organic beings hitherto discovered in the sandstone of the Connecticut valley. It was not till the completion of my last report in 1835, that I had any knowledge of their existence. Since that time, I have prosecuted it with encouraging success; and have brought to light many very remarkable facts, which I shall proceed to describe. In the American Journal of Science in 1836, I gave an account of seven species of these footmarks. But since that time, I have discovered more than twice that number of additional species. The general conclusions in that paper, however, are not invalidated by subsequent discoveries.

Not with a view to prejudge the nature and origin of these impressions, but chiefly to avoid circumlocution in description, I shall assume that they were produced by the feet of animals. Yet in the sequel, I shall present the arguments by which they are proved to be tracks. I shall frequently speak of them, also, as if they were really the feet of animals. Nor, as I can conceive, will this lead to error. For they are in fact, either casts, or moulds, of the feet that made them; and may, therefore, be spoken of as if they were petrified feet.

In prosecuting this subject, I shall describe these impressions under the following heads.

1. Their Localities.

2. A General Description of their nature and situation.
3. A Specific Description of the different kinds of footmarks.
4. Collateral Facts connected with the Subject.
5. Conclusions from the Facts.

## 1. *Localities.*

These impressions are confined to the new red sandstone formation, extending from New Haven in Connecticut to the north line of Massachusetts, and occupying most of the bottom of the valley of Connecticut river. We have seen that this formation has a slight easterly dip throughout most of its extent, and that a ridge of greenstone divides the upper from the lower beds, most of the distance. I have never met with any of the tracks in the sandstone below the greenstone; that is, on its west side. On the east or upper side of the greenstone, the greater number of localities occur not far from the greenstone.

The most northern locality is on the north bank of Connecticut river in Gill, nearly three miles higher up the stream than Turner's Falls. The spot is called the *Race*, or *Horse Race*, from the velocity of the current there. The rock on the north shore is a grey micaceous sandstone, a good deal resembling mica slate in hand specimens, having a dip of 30° southerly, and passing under the river without any intervening alluvium. It has been quarried there somewhat extensively; and thus have the tracks been brought to light. Several sorts of tracks are found here, quite distinct from one another. In general, however, the impressions on this sort of rock are not as distinct as upon some other varieties. I have never seen on this rock any other organic relic, vegetable or animal.

About eight miles south of the *Race*, on the east side of Connecticut river, is another locality; from which the first specimens ever noticed were produced. It is a quarry in red sandstone, in the south west part of Montague, less than half a mile from the river, and elevated above it not more than 100 feet. It is only a mile north of the locality of fossil fish in Sunderland; and such are the dip and strike of the strata, as to show that this quarry is higher in the series, by something less than 100 feet than the fish. The layer on which the tracks occur, was opened about 7 feet from the surface of the rock. It is a red micaceous sandstone, which splits very even, and is entirely free from every other organic relic. An adjacent layer, on which there were tracks, is a soft friable red marl, which crumbles to pieces easily. I have noticed only two species of the tracks here, and most of them are exceedingly distinct. In other parts of the quarry, I have noticed a few stems of vegetables.

The next locality in passing southerly, is in the north part of South Hadley; as much as two miles from Connecticut river, and 200 or 300 feet above it, on the hill south of a small stream, near Hale's Mills. The rock is a grey micaceous sandstone, laid bare in excavating the road leading from those mills to the center of South Hadley. I have seen here only two species, and obtained only a few specimens. From this vicinity, however, where are several quarries in a coarse gritty sandstone, a block was obtained many years ago, and long used for a door step by a farmer, which contains a fine example of tracks in succession, shown on Plate fig I cannot doubt but this originated from the vicinity of the above locality.

On the west bank of Connecticut river in the extreme southeast part of Northampton, at the eastern part of Mount Tom, is another interesting locality. The grey and red micaceous sandstone

and shale at that place, are laid bare by the river, for an extent of 70 or 80 rods, and several rods in width; and on their surface occur numerous examples of tracks of several species. The strata dip beneath the river at an angle from 10° to 15°, and have been scaled off considerably by the quarrymen. Some very good examples of tracks in succession occur here, although many of them are a good deal weathered. On some parts of this stone there are remains of plants, generally much broken: but I have not seen any in immediate connection with the tracks.

Near the village of South Hadley Canal, extensive excavations were formerly made through the shale, in constructing a canal. On one of the fragments thrown out, I noticed a single track.

On the fragments dug out at Mitineaque Falls, in West Springfield, in constructing the factories and the rail road, I have met with two similar isolated specimens on grey brittle shale.

The extensive quarry at the east end of the village of Cabotville in Springfield, furnishes some good examples of tracks. The rock there is chiefly grey and reddish shale, often abounding in septaria. Two layers at least, have been found here, abounding in tracks: one of them within 4 feet of the surface of the rock, and the other from 15 to 20 feet below it. On the north bank of the river, also, nearly opposite this spot, is another quarry, where numerous impressions of this sort were disclosed. They were found likewise several years ago, in excavating the canal for the sword and cannon manufactory of the Messrs Ames; to whose assistance I have been much indebted in pursuing my investigations at this place. Some vegetable remains, perhaps fucoidal, occur at these quarries. They are situated about half a mile from Connecticut river.

Between Cabotville and Springfield, on the east bank of the Connecticut, and considerably elevated above it, as well as several rods distant from it, I found several footmarks in the same sort of shale as at Cabotville. The spot is near the road from Cabotville to Springfield; and is a nearly abandoned quarry.

Chicopee Factory Village lies a mile and a half farther from the Connecticut than Cabotville, and on the Chicopee river. At the east end of the village is a bridge, near which ledges of rock extend across the stream, producing a considerable fall. In the bed of the river the rocks have been extensively quarried, and the work has disclosed many fine footmarks. The rock is either an exceedingly hard dark blue shale, or a fetid limestone; and well calculated to give distinctness to the tracks: though it is exceedingly difficult to obtain specimens here without taking very thick and heavy masses; so liable are they to break. Several species occur here, and by the kind intervention of Col. Joseph Bryant, I have been able to obtain at this place some remarkable specimens. At a quarry a few rods east of the bridge, on the south shore, I have seen a few tracks; and I was told that wherever quarries have been opened in the vicinity of these factories, they have always been found, and often many of them in succession. I doubt not that were the foundations of the factories and canals here to be torn up, they would disclose numerous interesting specimens. It was tantalizing to hear the quarrymen describe these relics in the ancient quarries; and mortifying to see with what *sang froid* they spoke of their being broken to pieces. I have no doubt but the whole region, for several miles square, near the mouth of Chicopee river, is underlaid by rocks abounding with these footmarks.

These are all the localities that I have found in Massachusetts. In passing southerly into Connecticut, the first quarry we meet, where they would be likely to be found, is on the bank of Connecticut river, near Enfield bridge, in Suffield. I have not seen any at the quarry: but have noticed a few specimens on blocks, said to have been brought from that place.

The next localities are in the vicinity of Hartford. They occur, though not abundantly, at the Rocky Hill quarries, a little west of that city. But the locality which I have found the most prolific in the whole valley, is at the north end of the principal street in Wethersfield, a little northeast of the States' Prison, where a low ridge of red sandstone projects into the river;

an arm of which passes behind it, so as to form a cove. This locality was pointed out to me by Professor Henry Hanmer, who graduated at Amherst College in 1837, and who resided near the spot. To him, and to his brother Charles Hanmer, I am much indebted for assistance in exploring this spot. It has furnished more species than any other locality; and the impressions are many of them as perfect as it is possible for a track to be upon tenacious mud. On the banks of a small stream, about 2 1-2 miles south of this place, and in the same town, I noticed a few tracks; but no excavation has been made there.

In Middletown some interesting examples of these footmarks were discovered by Dr. Joseph Barrat, and shown to me upon the side walks. The species are some of the most remarkable which I have found. The stones were brought from a quarry a few miles west of the city. They are mostly a quite coarse micaceous sandstone, sometimes containing pebbles half as large as rifle bullets.

At the extensive quarries in Chatham, I could not discover any footmarks. But Mr. Charles Hanmer pointed out to me a very distinct example, upon one of the stones forming the walls of the State Prison at Wethersfield. It may be seen in the front wall, on the west side of the entrance door. The rock of which this prison is built, was brought from Chatham quarries. And more recently I have met with other examples of tracks on stones brought from the same quarry.

It may be well, perhaps, to mention several places where the flagstones upon the side walks contain specimens of these footmarks. They occur on two or three door stones in the north part of the principal street in Wethersfield. I have seen a few upon the flagstones of Hartford. They are quite common in Northampton, though few of them would be recognized by persons who had not seen them more perfectly developed. Near the court house, and first parish meeting house, they may be seen; and it was from thence that I obtained by leave of the Selectmen, an excellent slab of which I shall give a drawing. They may be seen also in other streets, and in the front yard of John Hopkins, Esq. All these probably were brought from the quarries in the southeast part of the town, already described. I have noticed a few in Hadley, near the residence of Rev. Joseph Curtis. In Deerfield, a little south of the meeting house, they are common. These were brought from the Horse Race in Gill.

It appears from the preceding statements, that these impressions have been found at no less than fifteen localities, scattered over a linear distance, of about 80 miles: viz. from Gill in Massachusetts, to Middletown in Connecticut. The number of quarries where they occur, is still greater: but some of these being quite near each other, as those at Cabotville and at Chicopee Factories, I have considered them as belonging to the same locality.

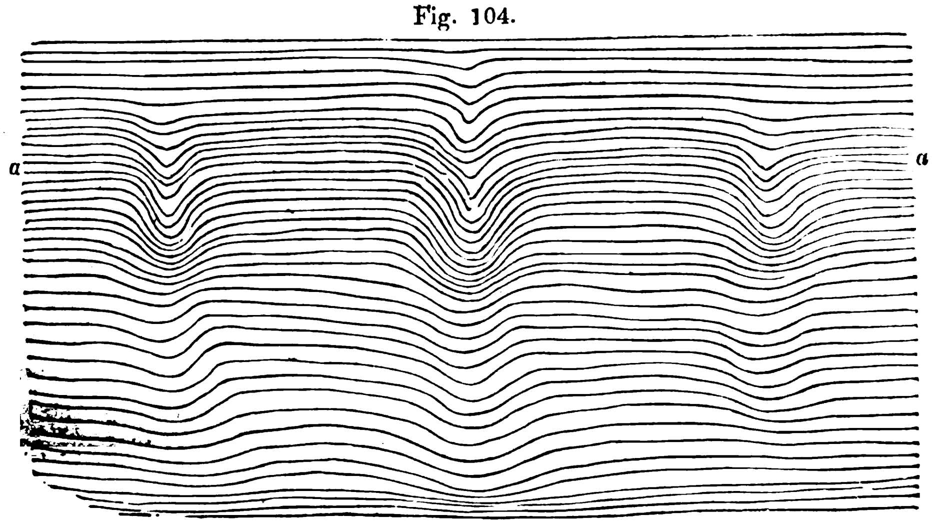
## 2. *A General Description of the Nature and Situation of the fossil footmarks.*

The first and most obvious idea excited in the mind by examining these impressions, is, that they were made by some substance pressing with considerable force upon the rock while it was yet in a plastic state, and causing the layers of mud clay to bend downwards. *Upon the upper surface of the rock, in its natural situation, the track is always a depression*, or a mould; and it is only when the rock is split and lifted up, so that we can examine its under side, that we find the tracks standing out in relief, or as casts. In the thousands of specimens that have come under my notice, I have never

seen one exception to this statement. A single well marked exception, indeed, I should consider fatal to the idea that they are the tracks of animals.

It is not merely upon one particular layer of the rock, that these impressions occur; but the depression is communicated to several layers; so that a vertical section across the three forward branches of the track, will present such an appearance as is shown on Fig. 104. Considerably above the middle of the specimen, as at *a*, *a*, the layers are most bent downward. Sometimes, indeed, they make almost a right angle with the general surface. In the layers above and below the layer that has been most bent, the curvatures become less and less, until they at length disappear, and no trace of the impression remains. They usually continue longer, both upwards and downwards, in the middle impression than on the side branches, because there the imprint was deepest. So that when the rock is split open near the top or the bottom, the middle toe only is visible. In such a case, we know that we are either above or below the layer on which the impression was originally made. In fact, it is not always easy to ascertain when we have opened the rock precisely at that place. If the rock be quite fissile, it is easy to see that several distinct specimens of footmarks may be obtained, all produced by one original impression; and these may likewise be so much like one another, and like the original, that they can hardly be distinguished. In some of the larger tracks, the impression extends vertically as much as 4 or 5 inches: but in the smaller ones, rarely more than two or three. It is usually difficult to separate the layers of the large tracks, so as to obtain more than one good specimen. But the smaller tracks frequently furnish several. In some instances we find upon one layer, probably that originally impressed, certain delicate markings, not seen upon the layers above or below: of which examples will be given when I come to give specific descriptions.

Fig. 104.



From the preceding statements, it seems a legitimate conclusion, that these impressions were not made by a solid body which remained upon the rock while yet in a plastic state, so as to be covered up by layers of mud subsequently brought over it. For in this case, although the inferior layers would be bent downwards, the superior ones must have been bent upwards, by folding over the foreign substance. This is, I believe, universally the fact, wherever any organic body, possessing much solidity, has become enveloped in rock: and where it is so evanescent as to leave only a trace, no perceptible curvature is produced in the layers, either above or below, except perhaps the case of the vesicular fucoids already described. Hence we may be sure, that the footmarks of this formation were produced by some body, that did not remain upon the mud after the impression was made.

The description that has been given above, of the curvatures in the layers produced by these impressions, is not exactly true in every case. Sometimes the rock below the impression is not slaty, and exhibits no lamination: and in such a case we see only the indentation on the surface. This is usually remarkably distinct; as is also the track in relief, upon the under side of the layer above the depression. But neither does the impression in such a case often extend upward; because the superior layer also is thick. The rock in these cases is usually very hard; which accounts for the distinctness of the impressions. Most of the specimens found at Cabotville and Chicopee Factories, are of this description.

There is another case in which the curvature of the layers extends upward but very little distance above the original track. It is where coarser or different materials from those composing the layer on which the track was impressed, were brought over it. Probably the indentation was thus at once filled up; so that the superinduced layer did not partake of the curvature.

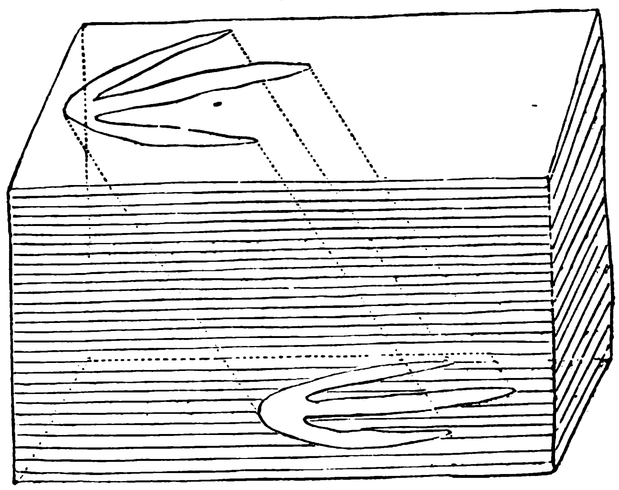
It could be only in very quiet waters that successive deposits of mud would conform to the depression: for the tendency of any agitation would be to fill it up. In the case under consideration, I have also frequently noticed, that the matter on the upper layer, that forms a cast of the track, is harder than the rock in general. Hence I conclude that the laws of coucretion have operated to some extent; as they are apt to do, where matter is consolidated in rounded cavities. It is, however, chiefly the thick toed varieties of the footmarks that exhibit this extra induration. And, indeed, it is chiefly these that I have observed to be sometimes filled up at once without affecting the superincumbent layers: as at the Horse Race in Gill, and in the southeast part of Northampton.

The more I examine the subject, the more convinced I am, that the curvatures in the layers extend downwards much farther than upward, from the layer where the impression was originally made. They are, also, much more perfect below than above that surface. This is a matter of considerable importance in ascertaining the precise shape of the track, and settling the species. For to do this, we want to get at the surface on which the impression was first made. Since on the layers above or below it may be somewhat different; or rather, some parts of the track may be wanting. Thus, in many cases we find a fourth toe upon one layer, but not upon the others; and the same is true of the heel. In giving an account of particular species, some cases will be given to illustrate the change which occurs, as we pass vertically from the original layer on which the track was made.

In a few instances I have noticed a singular peculiarity in the manner in which the curvatures in the rock, produced by the footmark, pass downward. Usually they descend perpendicularly

through the layers. But in this case the impression is communicated to the successive layers in a direction a good deal oblique to the layers; as is shown on fig. 105, which I trust hardly needs explanation. The track shown at the top of the block of stone, is continued downward in the direction of the dotted lines, so that the under side of the stone shows the tracks, as in the drawing, thrown a good deal forward. In one specimen in my possession, which is about 2 inches thick, the track is advanced beyond the perpendicular, not less than an inch and a half. In some cases the obliquity is on the other side of the perpendicular: that is, the tracks in the successive layers are farther and farther backward instead of forward.

Fig. 105



I explain this anomaly, by supposing that the mud on which the animal trod, was more or less inclined: in other words, that he trod upon a slope. The force of gravity would cause the layers to yield in a perpendicular direction; which would of course be oblique to their surfaces. In confirmation of this supposition, the most distinct specimens of this peculiarity in my possession, show a much deeper impression at the heel than at the toes: as would happen to an animal descending a slope.

I think, however, that we might explain a slight deviation of this sort from the perpendicular, by supposing that the successive layers of mud that were brought in to fill the track, were urged a little more and more forward or backward: or more likely, that the whole yielding mass, lying upon a sloping bottom, was slowly slid forward or backward by the force of gravity.

The varieties of rock on which these impressions have been found, are somewhat numerous. I have noticed the following: 1. A gray fine grained micaceous sandstone, rarely effervescing with acids. 2. A red do. containing no lime. 3. A gray hard not very fissile shale, sometimes slightly effervescing with acids. 4. This passes into an imperfect blue fetid limestone. 5. A soft red or gray shale, or marl, sometimes easily disintegrating, rarely containing lime. 6. A gray sandstone, with grains coarse enough to be easily perceived by the naked eye, in a few instances even containing small pebbles. The impressions are most distinct upon the limestone and reddish shale.

Whoever has seen the tracks of birds upon moist snow, but especially upon clayey mud, will have a very good idea of the appearance of the largest part of these fossil footmarks, even though he may not have seen a specimen. Many of them are as perfectly defined, and exhibit as distinctly the minutest markings on the foot, as any that I have seen of living animals upon snow or mud. Others, however, are much less distinct: but their outlines are quite obvious. Others are so nearly obliterated, as to be recognized only by the most practised eye. This is rarely the case, however, where the rock is newly split open.

Nearly all the impressions present three, and only three, toes, on the fore-part of the foot. The middle one is always the longest, and the inner one usually the shortest. A toe is sometimes seen coming out directly or obliquely behind; and very rarely there are four or five in front; as may be seen on Plate, 30, Fig. 1, and Plate 34, Fig. 15.

The numerous drawings on Plates, 30 to 49, inclusive, will give a better idea than description, of the varieties of these footmarks. They exhibit not only every species of the natural size, but also numerous examples, on a small scale, of tracks in succession, as they appear at the quarries. Still more satisfactory, to those who have the opportunity, will be an examination of the specimens, either of natural tracks, or of casts and moulds of the different species, in the State Collection. In my own collection, deposited in the Cabinet of Amherst College, the originals from which the drawings, casts, and moulds were taken, may be seen, with many other analogous specimens.*

A very striking difference is manifest among the specimens of footmarks, in respect to the thickness of the toes. While some of these are extremely thick, showing distinct protuberances and distinct claws at the extremity, as in Plate 36, also Plate 37, Fig. 21, and Plate 38, Fig. 37, others are extremely slender, and destitute of tuberose swellings and distinct claws; as in Plate 35; also Plate 43, Figs. 33, 34. There are, to be sure, intermediate specimens; yet I have never noticed any protuberances or distinct claws upon such specimens: And hence I bring together the narrow toed, under the name of *Leptodactyli;* (λεπτος and δακτυλος,) and the thick toed, under the name of *Pachydactyli,* (παχυς and δακτυλος.)

In the Pachydactyli, I have never seen a fourth toe, or any heel, except that which forms the basis of the toes. But in the Leptodactyli, we find some curious varieties of both these appendages. Perhaps the most simple form of the heel, is where the tarsal, or metatarsal bone of the

* It may be proper to say, that these footmarks were discovered in the interim between the publication of my last Report, and the present re-survey of the State: so that my Collection was chiefly made while I was not employed by the State, and at my own expense. Since that time, I have not been able, in all cases to obtain as good specimens for the State Collection; and have, therefore, sometimes substituted plaster casts and moulds of those in my own Collection. Similar casts and moulds, with a few natural specimens, have been sent to the Garden of Plants at Paris, the Mineralogical Institute at Heidelberg, the London Geological Society, the Hunterian Museum, and Rev. W. B. Clarke of England. And in this country, to the Boston Natural History Society, Yale College, the Military Academy, at West Point, the Lyceum of Natural History in New York, and to Francis Markoe, Jr. Esq. of Washington.

foot, has left an impression as far as the tarsal joint. The tracks of some living birds, (as the Penguin,) and of many lizards, is of this description. But in the fossil footmarks, the length of the heel is remarkable; as in Plate 33, Fig. 12. In this case, it is one and a half times as long as the middle toe. A short fourth toe proceeds from it, nearly at right angles, an inch and a half behind the junction of the three forward toes. In some cases, as in Plate 33, Fig. 11, we can see by the upward slope of the impressions made by the heel, that the whole of the tarso-metatarsus was not brought upon a level with the toes. In some instances, as in Plate 31, Figs. 5, 6, the fourth toe seems to have proceeded almost exactly from the tarsal joint. In the remarkable track, Plate 35, the heel had a circular form; and after it had sunk more than an inch into the mud, a fourth toe, like a sort of spur, made an impression, as shown in the figure. The five toed track, Plate 30, Fig. 1, shows a long heel, but no toe procceding from it.

In some cases, the heel seems to have consisted merely of an enlarged basis, from which the toes ramified. But in others, the toes appear to have been inserted a little above the general level of the foot, while a distinct heel projected downward, so as to leave a space between the heel and the toe, so that when these pressed upon the mud, it was forced up more or less into the vacancy; and the deepest impression of the track appears about the middle of the toes, and at the heel; while the two seem hardly to be connected; or are more or less separated by a ridge. In these cases, however, the impression of the toes is considerably the deepest. The heel did not reach the ground, till the toes had sunk some distance into it; so that the former is often wanting. Plate 40 and Plate 41, Figs. 28, 29, are of this description. The specimen from which Plate 40, was sketched, is particularly valuable for illustrating this point. While the enormous heel is most distinct upon the upper side of the slab, the toes are best exhibited upon the lower side. I think the latter must have sunk at least an inch into the ground, before the former reached it.

Connected with heels of this sort, there is a peculiar appearance that deserves notice. Small ridges and grooves radiate from the central part of the heel, on its posterior side, appearing as if produced by stiff bristles, or feathers. Such I formerly thought might have been their origin. But I give up that opinion. For even had these bristles existed upon the animal's heel, it seems hardly probable that they would so uniformly leave an impression that was regularly radiated. Again, I have seen them on successive layers, too far separated, (though but a small distance,) to have been communicated by the impression. I think they may be explained by supposing slight ridges, or rugosities, upon the animal's heel, so that when it was lifted up, the mud adhered to it more than to the other parts of the foot, and thus an irregularity of surface was produced, which was continued for a short vertical distance, as the impression was filled up. I do not feel perfectly satisfied with this solution; but I think it corresponds to the facts better than my former hypothesis.

It was an important point to be determined, whether these footmarks occur in succession. The drawings on Plates 47, 48, 49, will settle this point. They represent slabs from the different quarries that have been described, with the tracks occurring upon them; and although in several cases these are very irregular and confused, yet in most instances it needs no argument to show that they are continuous. Nor will the conclusion (to which I shall refer more particularly in the sequel,) fail to be forced upon the mind, that most of them must have been made by bipeds. The alternating right and left foot can in general be distinctly recognized.

* By using the term tarso-metatarsus, I do not mean to decide beforehand that these tracks are those of birds, in most of which the tarsus and metatarsus form but a single bone. But really, I did not know what other term to employ: for had I used another, it would have implied that the tracks are not those of birds.

This leads me to state a curious fact in regard to the Leptodactyli: It is less striking in the Pachydactyli. In many cases the toes of the right foot, are curved, often a good deal, towards the left; so as to bring the exterior side of the curve on the right side of the track. The left foot is curved in a similar manner towards the right. Plate 35, and Plate 41, Figs. 28, 29, are examples: as is also the five toed species, Plate 30, Fig. 1. It appears to have resulted in part from the effort of the animal in throwing its body forward. But in some of the cases referred to, I apprehend it resulted from the curved position of the toes of the foot. For by recurring to Plate 51, Figs. 96, 100, and 103, which represent the feet of living lizards, it will be seen, that some animals have feet of this description.

I have spoken of the right and left foot on the impressions, as if these could be distinguished. And in fact they often can be. Sometimes, indeed, where the tracks are in succession, they are almost exactly on a right line, as on Plate 38, Fig. 52, and there is no mark by which to distinguish the feet. But generally they are on the right and left sides of a right line; as a reference to Plate 48, Fig. 47, 55, will show: for these are sketches from different quarries, intended to be exact miniature representations: and can there be a doubt in such cases, but that the track most to the right, was made by the right foot; and the track most to the left, by the left foot? If in addition to this, we find the toes of the alternate tracks curving in opposite directions, will it not confirm this conclusion? Again, what I infer to be the inner toe of the track from the preceding marks, is almost always shorter than the outer one: And in the thick toed species, the angle of the heel, on the same side as the outer toe, extends farther back than the other angle. These two last marks may sometimes be employed to determine the right and left foot, where other evidence is wanting.

In the thick toed species, distinct claws at the extremity of the toes, are very obvious; as may be seen on Plate 36, and on Plate 37, Fig. 21, and Plate 38, Fig. 2. On the largest species, Plate 36, they are nearly two inches long; and in the smaller species, about one inch. They commonly proceed from near the middle of the curved extremity of the toes, unless where the foot was thrown a little out of its natural position, by the unequal pressure of the animal, in its efforts to move the body. In the narrow toed species, there is no claw perceptible, distinct from the toe. The toe, in this class, usually attains its greatest width, and sinks deepest, a little nearer the anterior than the posterior extremity of the foot: from thence it has a gradual taper to the end; sometimes of extreme fineness and delicacy. So that although the extremity was probably produced by a claw, the place where it joins the toe is not obvious. The claws of some living animals, especially birds, where they join the toe, are

almost exactly of the same width as the toe: so that their impressions in mud, would show only an uninterrupted taper, from the thickest part of the toe to the end of the claw, as in the fossil specimens. In a perpendicular direction, however, the claw of the living bird is not so thick as the toe; and one specimen of the thick toed footmarks, shows clearly that the same is true of that.

In the Leptodactyli, of course, we find no protuberances along the toe, produced by the articulations. But in the Pachydactyli, these are often very distinct; as may be seen on Plate 37, Figs. 20, 21, and Plate 38, Fig. 22. If I am not mistaken, the inner toe has uniformly two of these swellings, forward of the joint where it joins the tarso-metatarsus. In the middle toe, I think I can usually count three: But in the outer toe, they appear to be so much blended together that I can rarely number them. I shall recur again to these statements in the sequel.

The enquiry is often made, how deep beneath the surface of the rock these footmarks are ever found; and at what distance from, and height above, Connecticut river? And when the reply is, that at Cabotville, one layer of rock, on which they occur, is from 15 to 20 feet below the surface; that the quarry in the southeast part of Montague is nearly half a mile from the river, and nearly 100 feet above it, and that the locality in South Hadley is still more elevated and distant from the river; it produces surprise. But such enquirers usually suppose that Connecticut river has had some concern in the deposition of the solid sandstone rocks along its borders; and that the present depth of a footmark below the surface, shows how much rock has been formed over it since its formation. But the geologist is much more impressed, when he stands at the locality in Montague, and sees the layers containing the footmarks pass laterally under Mount Toby, at the distance of a mile or two; for he knows that this mountain, 800 or 900 feet above the quarry, shows only a part of the depth of rock that has been deposited in this valley since they were made. He knows, also, that the sandstone of the valley of Connecticut river, and of course the tracks which it contains, were formed long before the existence of that river.

### 3. *Specific Description of the Footmarks.*

In attempting to describe the different species of fossil footmarks that have been found, it will be necessary to settle some preliminary principles, as points of departure.

In the first place, what is to be understood by a *species*, in this case? In palæontology it is not always possible to give this term as restricted a meaning as in natural history: or rather, several species in natural history are often blended in a species in palæontology. But it is only because the characters of the fossil species are often too obscure to be distinguished. This is eminently the case in respect to the footmarks. For so slight is often the difference between the tracks of different species of the same genus, that they cannot well be distinguished. Nay, in the case of birds for instance, the tracks of different genera often differ too little to be obvious to the eye.

What I call species, therefore, among the footmarks, would probably be only genera in natural history. Indeed, some may suppose it preposterous to attempt to distinguish even genera by a simple track. For in the case of birds, whose tracks correspond more rarely than those of any other animals with those on stone, even the whole skeleton hardly furnishes sufficient data for such a determination. "The difference," says Cuvier, between two species, is sometimes entirely inappreciable from the skeleton. Even the genera cannot always be distinguished by osteological characters." *(Ossemens Fossiles, Tome Troisieme, p.* 524. *3d edition.)* But I suspect that these tracks are quite as characteristic as the skeletons. "The place where birds live, and the manner of their moving forward," says Dumeril, "are, so to speak, indicated beforehand by the disposition of their feet. Indeed, it is by the form and the length of the feet, and the disposition of the toes, that birds are divided into six orders, &c." *(Elemens des Sciences Naturelles. Tome* 2, *p.* 258. *4th edition.)*

## *Characters on which Species are founded.*

I shall found the characters of the different species, which I am about to describe, chiefly on two circumstances, viz. the form and the size of the tracks. The first particular will embrace several points: 1. the number of toes, whether 3, 4, or 5: 2. the shape of the toes, whether narrow, or thick and tuberose: 3. whether they are approximate to one another, or are divaricate: 4. whether straight or curved: 5. their relative length: 6. whether the track has a heel or not: 7. whether the heel be merely an impression made by the tarso-metatarsus, or by a distinct protuberance: 8. whether it have a toe proceeding from it: 9. its relative length.

Some may doubt, perhaps, whether a mere difference of size is sufficient to constitute distinct species. I have not often depended upon this character alone: Still, where the difference is quite large and constant, as in the *Ornithoidichnites ingens* and *elegans*, and *O. giganteus* and *tuberosus*, I conceive it to be sufficient. The contrary supposition is, that the smaller tracks are those of the young of animals that made the larger. But if we judge from the habits of living animals, we ought not to expect to find the tracks of the young in company with those of their dams, at a distance from the place of birth, until the feet of the young had attained a size approaching that of their parents. Especially we should not expect to find them in localities where none of their parent's tracks were to be found. In this case, also, we ought to find the tracks of every intermediate size, between the smallest and the largest; which is not the case in any instance where I have referred tracks of similar form to different species.

Where we make size the chief criterion of species, however, there is one source of error, which should be carefully guarded against. As fresh layers of mud were successively brought over the track, after it was impressed, it would be gradually filled up: and the extremities being the most shallow and narrow, would be first obliterated; and the tracks become shorter and short-

er; so that when the rock formed out of the mud should be cleaved open considerably above the original track, we should find the impressions indeed, but considerably shortened. But in this case the outlines will be indistinct; the claws will be wanting, and the toes too much rounded to be natural; so that we can usually determine whether we are much above or below the original footmark.

## *Classification.*

So numerous have been the discoveries of fossil footmarks in Europe within a few years past, and so many species occur in this country, that it will be at least convenient to have them designated by some appropriate scientific terms, and to arrange them in systematic order. I propose the term *Ichnolite* (ιχνος *a track*, and λιθος *a stone,*) to include them all; and to be the name of the Class. I would divide this Class into Orders, depending upon the number of feet possessed by the animal that made the tracks: *Polypodichnites,* (πολυς, πυς, and ιχνος) to embrace those with more than four feet: *Tetrapodichnites,* those with four feet; and *Dipodichnites,* the bipeds. The last order will embrace nearly all those found in this country; and the two first orders, nearly all those yet found in Europe. I shall in this place notice only those found in the Connecticut valley. I shall describe the following species in the order in which they here stand.

I have arranged these species under two sub-orders: the *Sauroidichnites,* (Σαυρος, ειδος and ιχνος) or those *resembling the track of a Saurian, or lizard;* and *Ornithoidichnites,* (Ορνις, ειδος and ιχνος.) or those *resembling the track of a bird.* These names, implying only resemblance, leave the real nature of the tracks open to discussion in the sequel.

### Class. Ichnolites.

### *Order. Dipodichnites.*

#### *a. Sauroidichnites.*

1. S. Barrattii.
2. heteroclitus.
3. Jacksoni.
4. Emmonsii.
5. Baileyi.
6. minitans.
7. longipes.
8. tenuissimus.
9. palmatus.
10. polemarchius.

### *b. Ornithoidichnites.*

1. *Pachydactyli.*

1. O. giganteus.
2. tuberosus.
3. expansus.
4. cuneatus.
5. parvulus.

2. *Leptodactyli.*

6. ingens.
7. elegans.
8. elegantior.
9. Deanii.
10. tenuis.
11. macrodactylus.
12. divaricatus.
13. isadactylus.
14. delicatulus.
15. minimus.
16. tetradactylus.
17. gracilior.

### 1. Sauroidichnites.

1. *S. Barrattii.* Toes five, directed forward, although usually much curved; very thick, and tapering rapidly towards the extremity; terminated by a distinct claw. Middle toe longest; length of the foot, excluding the heel, about 3 inches. Length of the step, 11 to 14 inches. Heel 2 inches long, and an inch wide. At its posterior extremity the impression of the tarsal joint is visible; and it seems that the leg did not rise perpendicularly, but was very much inclined. Plate 30, fig. 1, shows this species, of the natural size.

This very remarkable species was first pointed out to me by Dr. Joseph Barratt of Middletown, in Connecticut, upon the flagstones of that city; and on this account, as well as in testimony of respect for his scientific attainments, I have attached his name to the species. When he first showed it to me, I felt confident that I had at last found the tracks of a quadruped. But a careful examination of the only specimens yet found, does not confirm this impression: but rather the contrary. Only two slabs of stone, containing these tracks, have yet been found; and these are rather small, and a good deal worn by 15 or 20 years travel over them in the side walk. Plate 48, fig. 44, represents one of these slabs, presented to me by Dr. Barratt. Its greatest length is 30 inches, and its greatest breadth 20 inches. With the exception of four small tracks on the right hand side of this stone, all the footmarks belong to the S. Barrattii: although most of them are deficient in some part. At a, the five toes are quite distinct, and a part of the heel: the other part having been broken off. At b, all the track is effaced, except a part of the toes, which curve somewhat, and in a different direction from those of a. The same thing may be seen upon the other slab, Plate 48, fig. 45. And this I regard as perhaps the most

convincing evidence, that the animal which made these tracks, was a biped. For the trifid tracks, which were undoubtedly those of a biped, are often curved to the right and left in the same alternate manner, though in a less degree. c and d on Plate 48 Fig. 44, appear to be tracks of the same species, moving in an opposite direction. They are much worn by being trod upon so long, yet some of the toes are obvious. The distance between a and b is 13 inches: between c and d, it is about the same.

It occurred to me at first, that as both these rows of tracks are not far from the edge of the stone, they might have been made by the fore and hind feet of the animal, while the corresponding tracks on the other side are wanting. But the right and left curvature of the toes seems to show that this cannot have been the case. And besides, the tracks of a quadruped are not equidistant from one another, as those upon these stones are, but longer and shorter intervals alternate.

The other slab is in the possession of Dr. Barratt, and contains a greater number of tracks of the species under consideration. It is about three feet long; and Plate 48, Fig. 45, was painted by the artist from an accurate drawing sent me by Dr. Barratt, with a description. These I shall depend upon, rather than upon my own; since my examination was made in much greater haste.

It will be seen that this slab contains two rows of the five toed tracks, viz.: a, b, c, and d, g. The latter is interfered with by two trifid tracks, which are not probably connected with each other. There are also upon the stone, two distinct rows of thick toed trifid Ornithoidichnites; the largest of which Dr. Barratt has named the O. cuneatus; and which will be subsequently described. The five toed tracks show nothing but the toes; and a part of these are wanting. The length of the step of the S. Barrattii, according to the tracks d, g, is 10 1-2 inches; and according to the tracks a, b, c, 12 inches. The length of the toes in the latter series, is one inch and a half: in the other series, a part of the toes is wanting. The toes are terminated by a short nail.

A single track, similar in appearance to those just described, but with only 4 toes and a heel, may be seen upon the lower right hand corner of the stone. The toes are one inch and a half long; and the nail on two of them is very perfectly preserved, one quarter of an inch long. Dr. Barratt thinks it a different species from the S. Barrattii; and this is quite possible; although the absence of one toe may be easily explained upon a slab that has been so much exposed. Near this track is another with a heel and trifid anterior part.

The S. Barrattii occurs at Chicopee Factory Village, in Springfield; and, if I mistake not, in the north part of South Hadley. But in both these localities the specimens that have fallen under my notice, are obscure. And with Dr. Barratt, I strongly suspect that I have embraced two or three distinct species under this name. But I have not yet been able to seize upon the characters whereby they may be distinguished.

2. *S. heteroclitus.* Toes three in front, narrow, very much curved. Heel more than half an inch thick, and an inch long; stout, with a strong toe, three quarters of an inch long, proceeding nearly at right angles to the longest direction of the foot, from a point near the posterior extremity of the heel. Length of the toes, about an inch and a quarter, and all of nearly equal length. Exhibited of natural size and in relief, on Plate 30, Fig. 2.

I have only one well marked specimen of this singular species, which was procured at Wethersfield, and is so distinct that I do not hesitate to name and describe it. I have been able to

separate the specimen into several layers, so as to examine the track through its whole vertical extent. The drawing was taken from a layer near the middle. And I feel confident that it exhibits a natural and not a distorted foot mark. It is obvious that the animal's leg as far as the tarsal joint, made an impression.

I have a single specimen from Wethersfield, and another from the locality between Cabotville and Springfield, which differs from that just described, in having a quite short thumb on the inner side of the track. This character would form a distinct species: But as the heel is broken away in my specimens, I shall not name it as such. The specimen from Wethersfield is figured on Plate 34, Fig. 14.

3. *S. Jacksoni.* Toes three in front; narrow, and much curved; about of equal length, which is a little short of an inch. Heel narrow, an inch and a half long, curved in a direction opposite to that of the toes: small protuberance on the outer side of the curve, within half an inch of the extremity. Shown of the natural size, Plate 30, Fig. 3.

This species, no less heteroclitic than the last, occurs at Wethersfield, in the same rock with the S. heteroclitus: and it is possible that it may be a variety of that species. For in the only good specimen which I possess of it, and which I have been able to cleave into several layers, like the analogous specimen of the last species, there is a mark upon the uppermost layer but one, which might be regarded as a fourth toe, near the extremity of the heel. But that layer appears to be above the place where the animal trod, since, for the most part, the track is less distinct than on the two next layers beneath. Hence the fourth toe is not shown in the drawing. And even if it should be found that it belongs to this track, yet it differs from the S. heteroclitus, in the greater length of the heel, and in the much more slender and delicate character of every part. I have dedicated it to my friend, Dr. Charles T. Jackson, too well known to the scientific world to need any encomium from me.

4. *S. Emmonsii.* Toes three in front; middle one much the longest. Side toes nearly of equal length; proceeding from exactly opposite points of the middle toe, and making an angle with each other from 40° to 60°. Heel narrow, about half an inch long, with a strong fourth toe, an inch long, proceeding from its extremity, probably on the inside of the foot, and turned backward from a perpendicular to the middle toe. Length of the middle toe 2 to 3 inches: length of the foot from 2 1-2 to 3 1-2 inches. Deepest impression made by the heel and posterior part of the toes. Plate 30, Fig. 4, shows, what I suppose to be the left foot, of the natural size: Plate 31, Fig. 5, shows the right foot; and Fig. 6, an impression of the latter, as seen upon a layer of the rock, one half an inch below the surface from which Fig. 5, was copied.

I strongly suspect Fig. 7, Plate 31, to be a different species from the above; although closely resembling it. It is more common than the S. Emmonsii; is smaller, and rarely shows a fourth toe behind. The hind toe of the S. Emmonsii makes nearly as deep an impression as the heel; showing that it must have proceeded almost exactly from the tarsal joint, whereas in this variety, it must have been higher upon the leg. But I have too many doubts on the subject to allow me to mark it as a distinct species.

This species, to which I have attached the name of Professor Ebenezer Emmons, as a testimony of my high respect for his character, is found with remarkable distinctness upon the fine red slate of Wethersfield. At one spot there uncovered, the impressions of this and the following species are very numerous and distinct. An attempt is made on Plate 48, Fig. 46, to show a slab of these tracks; although the hind toe is omitted, as indeed it most frequently is in all the species that occasionally show it. Nearly all the animals that impressed this slab, seem to have been moving in the same direction: but so numerous are the tracks (they are not all shown in the drawing,) that I was not able to obtain the length of the step with certainty, in the present or the following species. Some other parts of the slab were so full of tracks, that perfect confusion was produced by their interference. Yet when they do not interfere, they are more distinct on this variety of stone than on any other that I have seen. Indeed, I have never but once seen tracks of living animals as distinct; and that was in Wethersfield, upon a clayey soil, resulting from the decomposition of this same red shale.

Fig. 6, of Plate 31, will give an idea of the manner in which tracks frequently change their appearance in a vertical direction. This layer was a little below that on which the animal trod, and, therefore, we see the heel shortened, and the toes near their junction, blended. In almost all cases the hind toe very soon disappears as we descend into the rock; showing that it did not make as deep an impression as the rest of the foot. Where the impressions are near to one another, as the toes, for instance, near the place of their separation on the foot, they are apt to become soon blended; as we should expect *a priori*. This circumstance is seen in the two left hand toes in the figure. The left hand toe appears to separate from the middle one, farther from the heel than the right hand toe. But Fig. 5, of Plate 31, shows that this was not the fact.

5. *S. Baileyi.* Toes three in front; middle one nearly twice as long as the others. Outer and inner toes unequal in length: making an angle with each other of only 30° usually, but sometimes as great as 40°. All the toes straight, and terminating behind in a long straight very narrow heel; at least an inch and a half long. Fourth toe proceeding from its extremity, and lying in various positions; but usually very much curved towards the line passing through the middle of the foot. Length of the middle toe, 3 to 4 inches: length of the whole foot, from 3 1-2 to 5 inches. Shown of the natural size, on Plate 32, Fig. 8; except that the middle toe is partly wanting: also a smaller specimen with a fourth toe, on Plate 32, Fig. 9.

This curious species occurs in connection with the one last described, at Wethersfield. Its great length, and the small divergence of the toes, render it very peculiar in its appearance. I have expressed a doubt as to the toe behind, for very few specimens show it: and those that have it, do not exhibit it in the same position. I have little doubt, however, but it was a slender toe that made the impression, which could be put into different positions.

Usually it is seen as shown upon Fig. 9, Plate 32. But I think it sometimes extends almost directly backwards from the tarsal joint; and in one instance it appears as if there were two hind toes connected with the same track. But this red slate is so full of tracks, that most probably one of them is the impression of some other foot. For it is not uncommon to see upon this slate the trace of a single toe, while all the rest of the track has been cleaved off with the superior layers of the rock.

Although this species, along with the last, is shown on Plate 48, fig. 46, as moving by several successive steps in the same direction, yet I could not satisfy myself from the short examination which I gave to the slab before it was broken to pieces, as to the length of the step in either species. Could I have studied it at my leisure, I might probably have done it; and yet, many tracks are omitted in the sketch to prevent confusion.

It is possible that this and the last species may prove identical. Yet the greater length of the heel in the latter, the smaller divergence of the toes, and the difference in respect to the fourth or hind toe, seem to make them too distinct to be confounded. I dedicate the present species to Professor J. W. Bailey, of West Point, so well known for his successful researches into the fossil infusoria of this country.

In examining the tracks of four footed living animals, I have often noticed that the hind foot frequently made an impression nearly in the same place as the fore foot. My attention, therefore, was arrested by finding at Wethersfield several specimens, probably of the species last described, in which one track overlapped the other more than half the length of the foot. I have given a sketch of one of these specimens in relief, on Plate 32, Fig. 10: although one of the toes is so near the edge as scarcely to be seen upon the drawing. But I examined in vain for any other evidence at the place that the animal was a four footed one. And when I consider the great number of the tracks at the locality, and that the majority of the animals seem to have been moving in the same direction, I doubt whether this interference of tracks may not have been accidental. The facts now stated, however, will lead future observers to examine this point narrowly.

I have been unable to decide in respect to the two last described species, whether it is the inner or the outer toe that is longest; because I could not trace a succession of tracks. But since in all other cases, where I have been able to settle this point, it is an inner toe that is shortest, I doubt not but it is so in the present case. It may be doubted, however, whether in all cases the difference may not chiefly be owing to the manner in which the animal planted its foot upon the mud, rather than to a real inequality. Yet the difference is often very striking.

6. *S. Minitans.* Toes three in front: middle one much the longest: inner one shortest: lateral ones spreading from 60° to 80°: all of them frequently somewhat curved: the middle one bending a little inward, and the other two a little backward. Heel narrow and long, rising a little as it extends backward, so that the impression rarely extends as far as the tarsal joint. Fourth toe proceeding from the inside of the heel, usually about an inch behind the junction of the other toes, and commonly bent forward near its extremity: rarely more than an inch long. Length of the middle toe, 3 to 4.25 inches: Length of the foot, 6 to 7 inches: of the step, 15 to 17 inches. Plate 33, Fig. 11, is a sketch of one of these tracks of the natural size.

I first found this species upon a very hard argillo-calcareous rock in the bottom of Chicopee river, at the Chicopee Factory Village. It was there very distinct; and as the fourth or hind toe was bent considerably forward, it had a quite threatening aspect; and hence I called it S. minitans. The specimen exhibited on Plate 33, Fig. 11, has less of this appearance than usual, because the hind toe slopes backward more than is common, and is not bent forward. It was obtained from a quarry on the north bank of Chicopee river, a little east of the village of Cabotville. It formed one of a series of tracks, eight in number, that had been laid open by the quarrymen, as shown in Plate 48, Fig. 47. Between the first and second track the stone had been broken away, and the distance was twice as great as between the other tracks: so that there can be no doubt but there were nine tracks originally. Only the first one showed a fourth, or hind toe, or much extent of heel; and, therefore, they are not shown upon the drawing. This proves that the absence of a fourth toe and a heel, in some cases, does not render it certain that none existed: and it shows the need of caution in deciding upon the characters of species. The distance between these tracks varied from 15 to 17 inches. One of them was considerably out of the direct route, as is shown in the drawing; as if the animal stepped a little aside. Such cases are very common in the tracks of living animals. See Plate 49, Fig. 74.

This species has been found, besides the other localities, at a quarry a little south of Cabotville, on the road to Springfield; in a loose specimen near a small stream between Hartford and Wethersfield, and at the Cove in the latter place. At the last locality, the track is considerably smaller than at Springfield; and my impression is, that it was made by another species of animal, though of the same genus.

7. *S. longipes.* Toes three in front, middle one longest: inner one shortest: lateral ones diverging between 70° and 80°. Heel very long: in some specimens, 6 inches: making an equally deep impression the whole distance. Fourth toe coming out from the heel, from an inch to an inch and a half behind the junction of the toes, at right angles nearly; half an inch long and on the inner side of the foot. Length of the middle toe, from 3 to 3.5 inches. Length of the foot, from 5 to 9 inches. Length of the step, from 15 to 17 inches. This species is shown of the natural size, on Plate 33, Fig. 12. The fourth toe is not here seen distinctly, in consequence of some disturbance in the mud after the track was made, whereby the long heel is made a little crooked.

I first found this curious species on the red and gray slates of Wethersfield. There I found several tracks in succession, which are shown on Plate 48, Fig. 48. I have not put upon this figure the fourth toe, because it was indistinct upon the stone in those particular tracks; although obvious upon others: and in all cases that I have seen, it was on the inner side of the foot. Indeed, I have seen it upon the alternate tracks in succession. If this species had differed from S. minitans only in the length of the heel, I should not have described it as a new species: since the animal might have the power of bringing down its heel horizontally, or of keeping it somewhat inclined. But the toes in this species are more divaricate: and more nearly of an equal length, than in S. minitans; and I have little doubt but they are distinct species. I have met with imperfect specimens of this, or an allied species, at Chicopee Factories in Springfield.

8. *S. tenuissimus.* Toes three in front: long, very slender, and all of them

much curved inwards: middle one somewhat longest. A fourth toe proceeds from the base of the other three, nearly at right angles to the direction of the middle front toe, and has about half as much length as that. It makes a deeper impression than any of the front toes, and is entirely straight. Length of the middle toe, and of course of the foot, 4 inches. Shown of the natural size, but considerably below where the animal trod, on Plate 34, Fig. 13.

This appears to be an anomalous and somewhat doubtful species. I have but one specimen, from Wethersfield, not perfect, and a still poorer one from the Horse Race in Gill. The former is evidently an impression somewhat below the layer where the animal trod; as only a part of the outer toe is shown. It is evident from this fact, that the greatest weight of the animal must have fallen upon the inner side of the foot, and upon the lateral toe. In the whole history of these tracks, I have never known another instance in which the hind toe made a deeper impression than the rest. Were it possible to refer this impression to any other species; that is, to consider it as a modification of any other, I should not describe it as different. But it is so peculiar that I cannot conceive of its having been produced by any other species. I therefore give it a place, not without many doubts whether I have exhibited its true character. I place it among the Sauroidichnites, rather than the Ornithoidichnites, because of the great curvature of its fore toes, and the peculiar form of the whole foot.

9. *S. palmatus.* Toes four, all directed forward: The three outer ones resemble very much the three front toes of most of the species already described; the middle one being somewhat, but not very much, the longest; and those on each side, nearly equal. The inner or fourth toe is very short. Heel broad, but short. Length of the foot, 2 1-2 to 3 inches. Length of the step, 8 inches. Shown of the natural size and in relief, on Plate 34, Fig. 15. See also Fig. 16, which is probably a smaller track of the same species in its natural condition; that is, impressed upon the stone.

I have met with this species only at the Horse Race in Gill, on a gray fine micaceous slate. The only specimen I have found, where the tracks are in succession, is delineated on Plate 34, Fig. 15. It will be seen from that drawing, that the animal which made the track, was a biped. For the short or fourth toe is found upon opposite sides of the foot in the different tracks; which would not be the case if it were made by the hind and fore foot of a quadruped; and the fact that both tracks point in almost exactly the same direction, is with difficulty reconciled to the idea that they were made by the hind and forefeet of a quadruped on different sides of the body. I regret, however, not being able to find more numerous specimens; as one is liable to mistakes in judging from a single specimen. The track from which Fig. 16, Plate 34, was sketched, was found at the same locality, and is a very distinct example. But it must have been made by the young of the S. palmatus, or else by another species of the same genus of animals. Its toes are slightly curved.

10. *S. polemarchius.* Toes three in front, very narrow and much curved inwards: middle one 11 inches long: lateral ones spreading from 40° to 50°: outer one 6 inches, and inner one 7 inches long. Heel 3 1-2 inches wide,

and extending back from the place where the toes are inserted, 4 inches. Near its posterior extremity, on the inside, a fourth toe proceeds, nearly 3 inches long, and almost at right angles to the direction of the middle toe. Fourth toe more than an inch above the bottom of the animal's heel: that is, the fourth toe does not make an impression so deep by more than an inch as the heel. Impression made by the heel and the toes unusually deep. On the posterior margin of the heel are fine radiated furrows, which are bent towards the inside of the foot. Length of the foot, 14 inches! Length of the step, 48 inches! Drawn of the natural size, on Plate 35, Fig. 17.

This species, so gigantic and formidable in its appearance, occurs on the argillo-calcareous rock of Chicopee river, near the Factory Village. The rock is very hard, and the specimens usually very distinct, but difficult to be procured. Through the liberal assistance of Col. Joseph Bryant, of Chicopee Factory Village, I have obtained two good specimens; of one of which Plate 35 is a copy. One is struck with the narrowness of the toes compared with their great length; and also with the remarkable size of the heel; not less than the hoof of an ox, or horse. But when we see how deep into the mud both the toes and the heel have sunk, we cannot but see why the latter was so large; nor can we doubt but the animal possessing it, must have been very heavy. It is certainly a very remarkable track.

In one spot I noticed what I have seen distinctly no where else in respect to any other track. Two tracks were so situated as to render it very probable that the biped animal stood still there. They were about 9 inches apart.

I regret that I did not have an opportunity to examine the place containing these tracks, till most of them had been either taken away by the quarrymen, or so mutilated as to be almost ruined. I have met with this species no where else, except at the quarry already described, between Cabotville and Springfield: and there the rock is too brittle to allow me to secure a specimen.

### 2. Ornithoidichnites.

#### a. *Pachydactyli.*

1. *O. giganteus.* Toes three, all directed forward: spreading a little more than 40°: middle one somewhat longest: inner one rather shortest: Average horizontal thickness, rather more than two inches: exhibiting distinct tuberous swellings. The inner toe has two of these, besides the enlargement where it connects with the heel: the middle toe has three, and the outer one still more: but so blended as to be not easily counted. Distinct claws proceed from near the middle of the rounded extremity of the toes: that on the middle toe, at least two inches long. Heel extending about 4 inches behind the insertion of the toes, and being about 5 inches wide: its outer posterior extremity extends farther back, than its inner extremity. The heel makes an impression not quite so deep as the toe. Length of the foot, including the claw, 17 inches! Length of the step, usually 4 feet: some-

times 6 feet! A specimen in relief is shown of the natural size, on Plate 36, Fig. 18.

Upon the whole this is the most remarkable species of fossil footmark in the valley of the Connecticut. It is remarkable chiefly, however, by its giant size: for in shape it corresponds almost precisely with the tracks of some living birds: although the great breadth of the toes is somewhat peculiar. I have carefully measured the foot of an African ostrich, the largest of living birds,—and on comparing it with the track under consideration, I find the latter to be just about four times the largest! The height of the ostrich, whose foot was measured, as he stood in his natural position, was about 8 feet. This species of ostrich, however, has but two toes.

But although of such enormous size, this is one of the most common tracks on the sandstone of this valley. The specimen delineated on Plate 36, was the first one that I found of this species; and although I had then seen many other species, and although this is as well marked as any other, yet it was not till after a long time that I could persuade myself that it was a track; so gigantic were its proportions. I found, however, that it was quite common at the locality in Northampton; more so than any other species. In several instances I found at that locality tracks of this description in succession; usually about four feet apart; but in one instance, six feet. Plate 47, Fig. 49, was sketched by the artist at this locality. It will be seen that there are four rows of tracks on this stone of the O. giganteus, which are parallel and point in the same direction. The row most to the right, has only three tracks, probably because at the lower part of the sketch they have been obliterated by the waters of Connecticut river, and at the right hand side, they are concealed by a mass of sandstone, not yet removed as deep as the surface containing the tracks. The second row towards the left, contains six quite distinct tracks, which extend about 20 feet. In this row the alternation of left and right foot is quite striking, as, indeed, it is in all the other rows. The third row contains nine tracks, and extends about 32 feet. These are not as distinct as the second row: still they may be recognized without difficulty by a little careful examination. The fourth row contains only three tracks. Probably these last were made upon a layer of rock above the present surface, and did not impress the surface except in three instances. Besides these rows, another crosses them almost at right angles, consisting of five tracks; and between the second and third, one has doubtless been obliterated. Two or three rows of smaller tracks may also be seen upon this surface, which are more or less broken. That surface has for a long time, I know not how long, been exposed, not only to the weather, but to be swept over by the water and ice whenever floods happen in Connecticut river. Consequently it is a good deal worn, and it requires considerable careful attention to discover all the tracks exhibited on the Plate. They are seen to the best advantage when the sun is two or three hours past the meridian.

In addition to the four rows of tracks on Plate 47 of O. Giganteus, which are parallel and point in the same direction, I have found at the same locality several other cases of the same kind, where the animals appear to have moved in the same direction. I infer from hence, that they were gregareous; and the same thing will be obvious in some other species, to be described. The rows of tracks are usually about 3 or 4 feet apart: about the distance at which a drove of horses, or cattle, would move.

The Northampton locality is the most northerly point where I have found the O. giganteus. But as we go south, this species occurs at Cabotville; at the locality between that village and Springfield; at the quarry on the banks of Connecticut river at Suffield; at Wethersfield; at Middletown, and at the Chatham quarries. Truly, the animals that made these tracks, must have been lords of this valley in their days.

I have already alluded to the great perfection of the tracks that occur in the fine red slate ot Wethersfield A few years since, an ice flood tore up a specimen of O. giganteus from that rock, and although considerably weathered before I obtained it, yet it presents an unique example of what I conceive to be *an impression of the skin of the animal's foot.* The most prominent appearance is that of fine corrugations, or wrinkles, especially near the margin of the track, and on the sloping sides of the toes. In some parts, however, especially on the heel, there are slight cross furrows, which produce small papillæ, exceedingly resembling those on the feet of some living animals, particularly birds. Plate 36, Fig. 19, is intended to represent this rugose and papillose appearance of the natural size, copied from a portion of the track.

The specimen described in the last paragraph, is in relief on the stone, and two of the toes exhibit the claws most distinctly. The under side of the animal's toes at the extremity, is a gradual curve, like the toes of most living animals, so that the greatest thickness of the toe is an inch back of the end. Yet the claw has nearly as great vertical thickness, except near its point, as the toe in any part. This causes it to form a ridge in bold relief on the under side, as well as at the extremity of the toe: that is, it seems to have made as deep an impression nearly through its whole extent, as any part of the toe. I rather infer from this fact, that there was a peculiarity in its structure, not found in the claws of living animals. But I have not examined those of living animals extensively enough to be confident that none would make an impression like the fossil footmark under consideration.

I have several times heard intelligent men, when shown the O. giganteus, make the inference that the track was originally smaller, but by some peculiar operation of the mud, (I know not what operation,) it became very much enlarged. And the same inference they extended to other tracks. But several circumstances seem conclusive against such a view. We find the length of the step proportioned to the size of the track; as may be seen by referring to the description of the different species. This makes it almost certain, that the animals that made the tracks, differed, either in size or the length of their legs, nearly in the same proportion as the tracks differ. Besides, even if we could conceive how a track could enlarge laterally, yet how could it possibly extend lengthwise and retain its shape, its heel, and its claws? I feel quite sure, therefore, that whenever we find a track upon the surface on which it was originally impressed, it will show us almost precisely the shape and size of the foot. The small changes produced in these respects in a vertical direction, have already been considered.

Among the multitude of tracks pointing in different directions on Plate 48, Fig. 53, which was sketched at the locality in Northampton, three may be seen in succession of the O. giganteus. The others are much smaller, and belong to the two following species.

2. *O. tuberosus.* Toes three in front; tuberous swellings remarkably distinct, and almost hemispherical: two on the inner or shortest toe; three on the middle toe, and a greater but indeterminate number on the outer toe. Claws distinct, from an inch to an inch and a half long. Middle toe very much the longest; lateral toes spreading from 25° to 35°; straight. Length of the middle toe, from 5 to 6 inches. Length of the foot, 7 to 8 inches. Length of the step, 18 to 33 inches. Shown in relief, but without claws, of the natural size, on Plate 37, Fig. 20: also on Fig. 21 of Plate 37, and Fig. 22 of Plate 38.

At first view this species may seem made by the young of O. giganteus, being about half the size of that species. But I have not met with intermediate specimens. The tuberous swel-

lings, also, on the small track, are more distinct and more nearly hemispherical than in the large one. The middle toe, likewise, in the former, is proportionally longer than in the latter. I have no doubt but they are quite distinct species. I find more difficulty in separating it from some of the species that follow.

The O. tuberosus is more widely diffused than any other species. At Gill I found a slab containing numerous tracks in relief, which had been used for a flag-stone at Turner's Falls, and which is now in my Cabinet, through the liberality of W. Woodbridge, Esq., Director of the Upper Locks and Canals on Connecticut river. It probably came from the Horse Race, which is three miles above the falls: But it may have been taken out at the falls, since extensive excavations have been made there in a similar rock. Plate 48, Fig. 50, shows a part of this slab; the tracks being in relief. At the locality in Northampton this species is common. The two rows of tracks on Plate 48, Fig. 52, I refer to the O. tuberosus; although they are much more delicate and slender than is usual, and the toes in the row in which the tracks are shortest, are more attenuated than in the other. Still the general form and proportion of the parts correspond to O. tuberosus; and I shall not describe them as different. On this slab, it will be seen that the animals were moving in almost exactly opposite directions. The tracks also follow one another nearly in a right line. The distance between them varies from 24 to 33 inches; which is certainly very great for the step of an animal with no larger foot. Part of the tracks on Plate 48, Fig. 53, at the same locality, and some of the smaller ones on Plate 47, Fig. 49, are probably of this species. It occurs, also, at Cabotville and Chicopee Factories, and at Wethersfield. Plate 48, Fig. 54, shows two rows of tracks of this species on a large door stone near the north end of the street in Wethersfield, on the west side of the street. The slab was doubtless obtained from the rock at the Cove, which is only a few rods distant. The length of the foot is 6 inches, and of the step from 21 to 24 inches. It exists, also, at Middletown; and the drawing on Plate 48, Fig. 45, has one row of three tracks, probably of this species. It occurs, also, at the Chatham quarries; as may be seen by a specimen exposed on the wall of the State Prison at Wethersfield, near the south door of entrance.

Plate 37, Fig. 20, was sketched of the natural size, from a specimen obtained at Turner's Falls, on the Montague shore. The claws are wanting; but the tuberose swellings, from which the specific name was derived, are very distinct. Plate 37, Fig. 21, was found at Chicopee Factories in Springfield, and shows the claws with considerable distinctness. Fig. 22, Plate 38, was from the same place; and shows the whole foot with remarkable distinctness, especially the claws. The toes spread more than usual; and it is altogether more delicate in every part than the O. tuberosus usually is. Yet at present I refer it to that species. It exists upon an argillo-calcareous rock, which is very hard; and there is an appearance upon the surface, as if a thin sea weed lay beneath the foot of the animal.

3. *O. expansus.* Toes three in front; tuberose; spreading from 50° to 70°: middle one somewhat longest: Claws distinct, an inch long: Heel narrow, somewhat wedge shaped. Length of the middle toe, from 4.5 to 5 inches. Length of the foot, from 6 to 7 inches. Length of the step, from 24 to 26 inches. Shown of the natural size on Plate 38, Fig. 23, and on Plate 39, Fig. 24, in relief.

This species differs from O. tuberosus in being much more spreading; in having the middle toe considerably shorter, in proportion to the others; and in having a wedge shaped heel. Nevertheless, it is often very much mixed with the O. tuberosus; as on Plate 48, Fig. 50, from

Turner's falls; and on Plate 48, Fig. 53, from Northampton; and there are not a few intermediate specimens as to divarication. But the shorter middle toe and the cuneate heel in the O. expansus, render it almost certain that it differs from the O. tuberosus, so as to form a distinct species. Plate 39, Fig. 24, is a very distinct specimen from Wethersfield: But the toes are more slender than is usual in the species, and it has less divarication. Yet I think it must be regarded as belonging to O. expansus, though it differs from the next species, the O. cuneatus, in little except size. The truth is, that I have been more perplexed wiih the species under consideration, and the preceding and succeeding species, than any others that I have described. And after doing the best in my power, I shall have several specimens which I cannot confidently refer to any species which I have proposed.

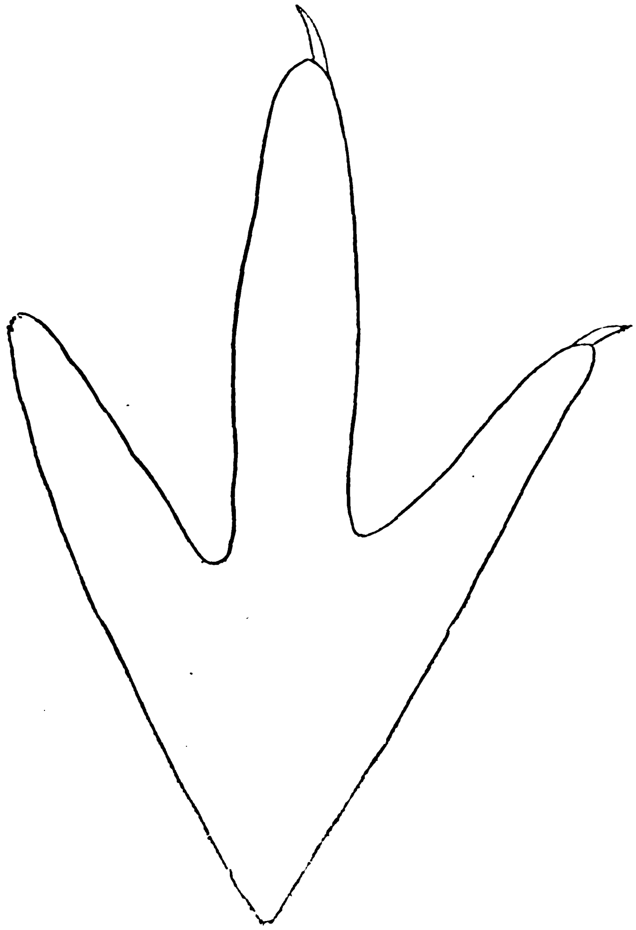
The O. expansus appears more as if made by a web footed animal, than any other which I have found. Yet I have never seen any indentation made by the margin of the web. But from observation upon the tracks of geese, upon the tenacious red clayey mud of this valley, I find that such an indentation does not always appear; though it does ordinarily. Perhaps the next species can lay nearly an equal claim to be regarded as web footed. Yet neither in this, has any distinct mark of the web ever been found.

**4. *O. cuneatus.* (Barratt.) Toes three, spreading at an angle from 60° to 75°: somewhat tuberose: middle one somewhat longest: Heel cuneate: Claws one third of an inch long. Length of the middle toe, 2.5 inches: Length of the foot, 3.5 to 4.5 inches: Length of the step, from 8 to 12 inches. Shown of the natural size, but smaller than usual, on Plate 39, Fig. 25.**

I am indebted to Dr. Joseph Barratt for the name and distinguishing character of this species. He calls it O. cuneatus, from the wedge shaped form of the animal's foot. A row of five tracks of this species is shown upon Plate 48, Fig. 45, which was copied from a slab found in Middletown, and has been already described. Dr. Barratt has sent me an outline of one of these tracks, which is given in Fig. 106, on the next page. The claw on one of the toes is wanting. The steps on this slab vary from 8 to 10 inches. Dr. Barratt adds, that "the shortness of the step, and the depth of the impression, indicate a short-legged heavy bird. On another paving stone, I have found two tracks of this species, in bold relief; one of which is in advance of its fellow, only an inch and a half; and their margins approach within half an inch, indicating that the bird there stood still."

This species is found at Wethersfield, and in the north part of South Hadley. I have in my cabinet a specimen of coarse gray gritstone, long used by a farmer in South Hadley for a door step, which contains four distinct tracks of this species in relief, as shown on Plate 48, Fig. 55. The length of the foot is about 3.5 inches, although the claws are wanting, and most of the protuberances on the toes, probably from long use. The distance between the tracks is about 10 inches; and they furnish a fine example of a succession of steps. They are not upon a right line: but if a line be made to connect the centers of the first and last tracks, the heel of the two intermediate ones, will lie the one 2 inches to the right, and the other 2 inches to the left of the line. I infer from these facts, that the body of the animal that made them, must have been rather broad, and its legs short; since such is the manner in which living animals of this description make their footmarks upon the mud: as may be seen by the sketch of a row of goose tracks on Plate 50, Fig. 81.

Fig. 106.



I cannot point out any important difference between this species and the O. expansus, except their size, which is nearly double in the latter to what it is in the former, and that too in linear extent. I cannot believe that so great a diversity in this respect is consistent with identity of species: though this point may not be considered so certain as it would be desirable to have it.

5. *O. parvulus.* Toes three, probably with claws, spreading but little: middle one considerably longest: one of the lateral ones shortest. Length of the middle toe, 0.5 inch to 0.8 inch. Length of the foot, from three quarters of an inch to an inch and a quarter. Length of the step, 5 inches. Plate 39, Fig. 26, shows the only specimen and all the tracks of this species that I have seen. They are in relief.

The shape and proportions of this species are almost exactly like those of O. giganteus: but how different in size! I have never seen an example of it except on the slab from the side walks of Middletown, sketched on Plate 48, Fig. 44. Near one side of this stone, where the surface is but little worn by the tread of men, are the four tracks represented of the natural size on Plate

39, Fig. 26. The successive tracks are brought twice as near to each other on the drawing, as they are on the stone. But some slight protuberances about midway between them, have led me to suppose that another track once existed there: Yet I do not feel quite confident of it: for the indications of it are very slight. If no such track existed, then the length of the step must have been 10 inches; which is out of all proportion for so small a foot.

The most remarkable circumstance about this track, is the occurrence of two impressions together, of very unequal size: the smaller one occupying the same relative position in respect to the larger one in both instances, except that it is on different sides of the foot. The enquiry is very natural, whether they were not made by a marsupial quadruped, whose fore feet were much smaller than the hind ones. This might be a probable conjecture, were not the shape of the tracks so much like that of the other Pachydactyli, which have been described: and it seems to be settled beyond all reasonable doubt, that all these were formed by bipeds. I cannot suggest any other method of explaining this anomaly, unless it be to resort to the supposition that the smaller tracks were made by the young of the larger animals that formed the layer: and in that hypothesis I have but little confidence. Probably the discovery of a few more tracks of this kind might clear up the difficulty, which I confess myself at present unable to solve. I ought perhaps, however, to suggest, that it is possible these are not real tracks, but rather examples of those vermiform bodies, which are not unfrequent on the sandstone of this valley, and a specimen of which is exhibited on Fig. 98. For on other parts of the stone containing these supposed tracks, are some slight protuberances, a little analogous to these, yet not showing any tendency to a trifid arrangement. Indeed, it would be passing strange, if in the space of a few inches, four of these vermiform bodies should assume the exact form of tracks, when I have never noticed any tendency to such a form in all the more distinct specimens which I have seen. In short, I may as well cease attempting to solve this enigma, until more light shall come from further facts.

### *b. Leptodactyli.*

6. O. *ingens.* Toes three in front, narrow, tapering to a point; spreading between 50° and 60°: middle one somewhat longest: the lateral ones about equal: deepest impression made by them forward of their middle part. Heel large, making its deepest impression several inches behind the junction of the toes, and leaving a ridge between the toes and the heel: not sinking as deep as the toes by at least an inch. Radiating ridges and furrows proceeding outward from the center of the heel upon its anterior slope. Length of the middle toe, in the longest specimen, from the middle of the ridge between it and the heel, 15 or 16 inches: Length of the heel from the same point to the extremity of the radiating ridges, 8 or 9 inches: Length of the whole foot, from 23 to 25 inches! Length of the step, from 40 to 72 inches! Shown of the natural size on Plate 40, fig. 27.

This species occurs only upon the blue shale at the Horse Race in Gill, and I have not succeeded in obtaining but one or two perfect specimens. Plate 40, Fig. 27, gives a less distinct view of the species than the specimen itself. It is necessary, however, to examine the heel on the upper side, and the toes on the under side, in order to see them distinctly; because the latter are a good deal filled up where the heel is most obvious: But the heel scarcely shows itself on the under side, where the toes are most distinct. Only a few of the largest specimens

of these tracks appeared at the locality, and these were injured by the quarrymen. The step however, was six feet; and in one or two of the tracks, it seemed as if the animal was moving rapidly; or down hill, for the mud would seem to have been crowded forward a little, so as to form a ridge around the track, two or three inches high. Indeed, the impression made on the mud was nearly as deep, and the pressure apparently almost as great, as I have seen from the tread of an elephant on mud. It is difficult to determine from the very gradual slope of the posterior part of the heel upwards, precisely how far backward the knob that made the impression extended. But if, as I have suggested, the ridges and furrows owed their origin to the rugosities of the skin on the heel, it extended back as far at least as these extend: And this would make the entire length of the track two feet! But truly gigantic as these dimensions appear, and far surpassing as they do all analogous living animals, I am of opinion that the animal which produced this track, was not as large and heavy as that which formed the O. giganteus. For the narrow toes of the O. ingens, (which are not well shown in the Plate,) have not half as much under surface as those of O. giganteus: So that when the heel did not reach the ground, as was probably in general the case with the O. ingens, the basis of support was far less than in the O. giganteus, and yet, the depth of the impression was, to say the least, quite as great in the latter as in the former. And even when the heel was brought in contact with the mud, the under surface of the foot must have been less in the O. ingens than in the O. giganteus.

It is obvious, however, that the depth of a track is no sure index of the weight of the animal: for this must in a great measure depend upon the state of the mud. But it is safe to calculate the weight of the animal from the means which Providence has provided to prevent its sinking in the mud; since the adaptations of nature to animal wants are made with almost mathematical precision. And as above remarked, the entire surface of the O. ingens must be considerably less than that of O. giganteus; and, therefore, I infer that the author of the latter must have been lord paramount in this valley. But after all, this is only a question which of two confessedly enormous giants was the largest.

That the object of the heel of O. ingens was to prevent the animal from sinking too deep in the mud, must be manifest to every reflecting mind. Equally obvious is it that the thick toes of the Pachydactyli would serve a similar purpose. And in these facts we perceive evidence that the same infinite wisdom was in exercise in those remote ages of the world, to adapt the organs of animals to their varying conditions, of which we now witness so many remarkable exhibitions.

In another part of the same quarry at the Horse Race, in which occur the specimens of O. ingens, that have been described, we find a series of tracks, probably of the same species, but considerably smaller. They are wanting in the heel altogether; and I apprehend that the layer on which I saw them, was below that on which the animal trod. The middle toe is 12 inches long, and the length of the step varies from 42 to 45 inches. The row varies considerably from a right line; and the right and left foot are obvious. The series is shown on Plate 49 Fig. 56.

7. *O. elegans.* Toes three in front; spreading about 60°: middle one much the longest and stoutest; gracefully curved inward: lateral ones turned outward from the middle toe, near their extremity: inner one considerably shortest. None of the toes are apparently connected with the heel, which is more or less separated from them by a ridge, nearly as high as the general surface of the stone. The deepest impression is made by the middle toe near its middle part; and here it sinks nearly half an inch.

deeper than the heel. Heel rather oblong, showing small ridges and furrows at the bottom, which give the posterior part of the track a scopiform appearance. Length of the middle toe, from 4.5 to 6 inches; of the outer toe, 3 inches; of the inner one, 2.5 inches. Length of the whole foot, including the heel, from 6 to 7 inches. Length of the step; from 12 to 21 inches. Shown of the natural size on Plate 41 Fig. 28. Also on Fig. 29, is sketched a more slender specimen, with the toes remarkably bent inwards.

This very distinct and handsome species was the one that first called my attention to the subject of footmarks; and at the most northerly localities it predominates over all the other species. In its general shape, and also in its heel, it very much resembles the O. ingens. But I must believe it to have been produced by another species, probably of the same genus. In the majority of cases, the heel is wanting: but the toes of this species alone can in general easily be distinguished by the gracefulness of their curves, the depth of the impression made by the middle one, and its great relative length.

Plate 48, Fig. 57 is a slab containing the O. elegans, from the southwest part of Montague; and is the first specimen of fossil footmarks that ever fell under my notice; having been pointed out to me by Dr. James Deane of Greenfield. They are exceedingly distinct, though few in number. Two animals appear here to have been proceeding in the same direction. A third track just begins to show itself in continuation of the right hand row upon the edge of the stone, though the whole slab is not shown in the drawing. I have the slab which was split off from this specimen, and it shows the tracks very perceptibly in relief.

Plate 48, Fig. 58, shows one row of ten tracks and another of four, probably of this species, although the heel is wanting, as they appeared upon the blue slate at the Horse Race. The length of the step here was only about 12 inches, and the length of the toes, 4 inches. It may hence be reasonably doubted whether this example ought not to be referred to a different species. But at present I prefer to bring them under this species. Had the drawing been enlarged, many other tracks might have been brought upon it; and, indeed, it does show a row of smaller tracks, crossing the row first described, almost at right angles; and one insulated track.

Figs. 59, 60, 61, and 62, Plate 48, are all sketches of slabs in my cabinet from the Horse Race; all the tracks being probably the O. elegans. Figs. 59, and 60, are depressed tracks, or tracks in their natural position. But Figs. 61 and 62, are in relief. The tracks vary from four to six inches in length, and the heel is rarely visible. On Fig. 59, the succession of steps is quite obvious, although this layer, having been probably a little below that on which the animals trod, causes the tracks to be less distinct than usual. In general they are exceedingly distinct upon these slabs, which are all gray fine micaceous sandstone, or shale, resembling not a little that variety of mica slate which is passing into argillaceous slate. On Figs. 60, 61, 62, the tracks appear for the most part unconnected; yet some of them are in succession; and as the slabs lay in the quarry, the most of them were connected with others beyond the limits of the parts here sketched.

Plate 41, Fig. 29, is a remarkably distinct and quite peculiar specimen on the red slate of Wethersfield. The toes are so much more slender than the specimens already described, that I was at first inclined to refer it to the O. macrodactylus, to be hereafter examined. But the heel in that species seems to be little more than the continuation backward of the middle toe. Whereas in this specimen a ridge rises behind the toes, before any heel appears; as is the case with O. elegans and one or two other species. And although the heel in Fig. 29, is broken off, if one existed, yet I have little doubt but the specimen ought to be regarded as O. elegans; and I suppose

the toes appear more slender because the impression was made upon different mud, from that on which the other tracks of this species were formed.

This species is the O. diversus α clarus, of my memoir in the 29th volume of the American Journal of Science. I have not met with it at any quarry south of Montague, except at Wethersfield.

8. *O. elegantior.* Toes three in front, spreading about 70°: middle one much longer than the others, and broader towards its anterior part, where the impression is much deeper than in any other part of the foot. Middle toe slightly curved inward; lateral ones straight: inner toe shortest. Slight radiating ridges and furrows behind the heel, but no distinct impression of a heel, on any specimen in my collection. Length of the middle toe, 2 to 2.5 inches: including the radiating ridges, 3.5 inches. Length of the step, from 5.5 to 9 inches. Shown of the natural size on Plate 42, Fig. 30: the largest track on that drawing being of that species.

I cannot point out any well marked distinction between this species and the O. elegans, except in size. It might, therefore, have been made by the young of the former species: but where the difference in size is so great, I am not disposed to adopt that view of the subject. I have therefore, made a new species of it. The absence of the heel probably resulted from the fact that the layers on which the few specimens in my Collection occur, were below that which received the impressions of the heel. Yet the presence of radiating ridges and furrows behind the toes, serves to confirm the explanation which I have given of this phenomenon, since it shows that this appearance may be communicated some distance downward. But I apprehend this was done rather by the lifting up of the mud, as it followed the heel, than by the pressure downward. This species is distinguished from all others, except the O. elegans, by the graceful curvature of the toes, and by the swelling out of the middle one towards its anterior part, and the great depth of the impression there.

I have not met with this species except at the Horse Race in Gill, in the southwest part of Montague, where it occurs with the O. elegans, and in the north part of South Hadley On Plate 48, Fig. 58, the row of five small tracks, crossing the rows of O. elegans at the Horse Race, belongs to this species. In that row the distance between the first and second track is double to that between the other tracks. I hence infer that one has been there obliterated. In the specimen from South Hadley, the distance between the steps is 10 inches, and the right and left foot can be distinguished by the curvature of the middle toe.

This species is the *Ornithichnites diversus β. platydactylus*, of my memoir in the 29th volume of the American Journal of Science.

9. *O. Deanii.* Toes three in front, quite narrow, spreading from 60° to 70°: middle one considerably the longest and slightly curved inward: inner toe shortest: lateral toes very much curved outwards, especially towards the anterior extremity. Heel broad, attached immediately to the toes, or with only a slight elevation between them, making an impression as deep as the toes: sometimes delicate radiating ridges and furrows appear at its anterior part, but usually they are wanting. Length of the middle toe, from 2.5 to 3 inches: length of the whole foot, 4 to 4.5 inches. Length of the step, 9

to 12 inches. Shown of the natural size on Plate 42, Fig. 31. Fig. 32, Plate 42, shows also a specimen in which the toes are less divaricate than usual, and slight ridges and furrows appear around the heel; which makes but a slight impression.

This species approaches nearer to the O. elegans and elegantior than to any other. But it differs from them in being far wider where the toes are connected with the heel, in having the toes connected with the heel without an intervening ridge, in the much greater outward curvature of the lateral toes, in having all the toes more narrow, and in the middle one's not sinking deepest towards its tip. It is a beautiful species, and the specimens of it on the fine red shale of Wethersfield, where alone I have met with it, are very perfect. I have dedicated it, as a testimony of respect, to Dr. James Dean of Greenfield, who first called my attention to the subject of fossil footmarks.

10. *O. tenuis.* Toes three in front, spreading from 50° to 60°: very slender: middle one much the longest and nearly straight: lateral ones curved outwards: inner one shortest. Heel broad where connected with the toes, but rarely making an impression, so that its precise form has not been ascertained. Length of the middle toe, about two inches: of the foot, 2.75 inches: of the step uncertain; probably about 7 inches. Shown of the natural size, but less slender and delicate than usual, on Plate 43, Fig. 33. Fig. 34, shows a more delicate specimen, but not an unusual one.

The form and proportions of O. tenuis scarcely differ from those of O. Deanii: but there is usually a slenderness and delicacy about the former, that pretty clearly mark it from the latter; although both I doubt not were made by congeneric animals. It also differs too much in size from the O. Deanii, to be placed under the same species, according to my views of the matter. The sketch of this species on Plate 43, Fig. 33, was taken from a specimen less slender and delicate than is usual, but Fig. 34, shows one much more attenuated. It is a very distinct and beautiful track; and occurs somewhat plentifully upon the fine red slate of Wethersfield. But the tracks being numerous and much confused, I did not trace out the successive steps on the stone, till it was broken into small specimens; so that I am doubtful as to the length of the step. It probably occurs, also, at Chicopee Falls: but I cannot certainly identify the specimens.

11. *O. macrodactylus.* Toes three, all in front: diverging from 40° to 55°: very slender: middle one straight, and almost twice as long as the inner one, which is the shortest: lateral toes nearly straight, slightly curving outward near their tips. Heel rather short and very narrow; being little more than a prolongation backward of the middle toe. Impression nearly of equal depth in every part of the foot. Length of the foot from 5 to 6 inches. Length of the middle toe, from 4.5 to 4.7 inches. Shown of the natural size, but with rather thicker toes and more spreading than usual, on Plate 43, Fig. 35.

This species is distinguished from all others by the great relative length of the middle toe; by the small divergence of the lateral toes; by their straightness; by the character of the heel,

and the uniform depth of the impression over the whole foot. The drawing on Plate 43, Fig. 65, was made from a specimen of which the toes were a little wider than usual; perhaps because the layer of rock containing it may have been a little below that on which the animal trod. The middle toe also, by some subsequent movement of the mud, is turned sidewise near its tip, Usually the middle toe, at the bottom of the impression, is little wider than the blade of a knife, and the layers of rock are bent downwards almost perpendicular to the surface. The impression of this toe, also, sometimes exhibits a slightly serpentine or waving course as if the very slender toe was bent one way or the other: although this appearance may have been produced by some slight lateral movement of the mud after the impression was made. This species I have met only at Wethersfield and Cabotville. At the latter place, the tracks are in succession: but I had opportunity to measure none which were satisfactory to obtain the length of the step. The specific name (long-toed,) refers particularly to the middle toe.

Under O. elegans I have already given the reasons that lead me to suppose that the specimen on Plate 41, Fig. 29, should be referred to that rather than to the present species.

**12. *O. divaricatus.* Toes three, all in front; thick, spreading from 75° to 85°: lateral ones somewhat curved outward towards the tip; nearly equal in length: the inner one rather shortest: middle one about one third longer than the others: considerably curved inward: all of them acuminate. Heel entirely wanting. Length of the foot to the point where the toes meet, 4 to 6 inches. Length of the step, 15 to 21 inches. Shown of the natural size in relief, on Plate 44, Fig. 36; also on Fig. 37.**

No species of the Leptodactyli has so thick toes as this: and had I been able to satisfy myself that it has distinct claws proceeding from the rounded tip of the toe, like all the Pachydactyli, I should have placed it under that family. Not improbably it ought to be placed there. But most of the specimens of it in my possession have been used for flagging stones until they are much worn, and thus the precise character of the toes is very much obscured. However, this is not a point of much importance: although no one can examine the specimens of footmarks without seeing at once, that there is a very obvious line of distinction between the Leptodactyli and the Pachydactyli. That the O. divaricatus is a distinct species, is very obvious. The wide spread toes, their approach to equality as to length, their thickness, and the absence of a distinct heel, mark it off from all others. In form it comes nearest the O. expansus: but this is one of the thickest toed species; and even if O. divaricatus should be found to belong to the Pachydactyli, it will be one of the narrowest toed species of that family.

Northampton is the locality most abounding in this species. Plate 48, Fig. 63, represents a slab, which the Selectmen of Northampton allowed me to replace in the sidewalks of that place, by another stone, and it is now in my cabinet. A row of O. divaricatus proceeds from each of the lower corners towards the middle of the opposite side. Although a toe is effaced on two of the tracks, yet upon the whole, the examples which they present are very striking and satisfactory. The distance between the tracks is uniform; being 22 inches in the left hand row, and 20 inches in the right hand row. The size of the track, also, and the divarication of the lateral toes, correspond almost perfectly on the different tracks. The curvature of the middle toe, also, towards the general line of direction of the steps, is quite striking, and points out very distinctly the right and left foot; as does also the position of the tracks on the right and left side of the general course of the steps. This slab was obtained from the quarries in the southeast part of Northampton.

Plate 48, Fig. 64, shows another slab from the same locality, which I was allowed to replace by another, in the front yard of Dr. Sylvester Graham, at Northampton, and it is now in my cabinet. It contains two rows of tracks. One of them shows the parts of only two tracks, which appear to be the same as those sketched on Plate 48, Fig. 63. The other row contains five tracks, very divaricate, considerably removed to the right and left of the general course, and the middle toe is a good deal curved to the right and left; so that the right and left track can easily be distinguished. In all these respects, as well as in the absence of a distinct heel, this track corresponds to the O. divaricatus. Yet the track is considerably smaller, being only about 4 inches long, and the step 15 inches; except the last one in the row, which is only 12 inches. It may not, therefore, have been made by the same species of animal as the O. divaricatus on the other slab: but I shall regard them as identical. But as they are considerably worn, it is not impossible that they belong to the O. cuneatus, which they somewhat resemble in size and form.

The O. divaricatus is rather abundant at the quarry near the east part of the village of Cabotville, where they existed, as the quarrymen informed me, in rows of considerable extent. Fig. 37, Plate 44, shows also a remarkably distinct specimen in relief on the red slate of Wethersfield, which I am disposed to refer to this species. There we see a small but distinct heel, which is the principal objection against considering it as the present species. If it be not this species, I can think of no other to which to refer it, unless it be an anomalous variety of O. Deanii. But that the O. divaricatus must have had a heel, cannot be doubted. My supposition is, that the toes were inserted into the heel at so elevated a point, that generally the toes only reached the mud.

The animal that made the O. divaricatus must have been a stout one, with a rather wide body; as appears from the distance to the right and left of the general course, at which the tracks were made. The length of its leg, also, must have been considerable; although not as great as that of some other of these animals of sandstone days.

13. *O. isodactylus.* Toes three, all in front: straight: lateral ones spreading from 90° to 120°; rarely more than 110°: nearly equal in length: usually straight: rather stout. Heel indistinct, often wanting, and the stone raised above the general surface where the toes unite. Length of the foot, from 1.5 inch to 2 inches. Length of the step, 4 inches. Shown of the natural size, but more than usually divaricate, on Plate 45, Fig. 38: also on Fig. 39.

This species is the O. minimus of my memoir in the 29th volume of the American Journal of Science: but having discovered still smaller tracks, it became desirable to attach another name to this species; and the term *isodactylus*, or *equal-toed*, which I have taken the liberty to construct from the Greek ἴσος and δάκτυλος, expresses a character which is more nearly true of this than of any other species; viz. an equality in the length of the toes. The middle toe, however, is always longest. Its most common locality is the Horse Race; where I found several tracks in succession, which were 4 inches apart. I have also referred some specimens to this species from Wethersfield; one of which is figured on Plate 45, Fig. 39; not however without doubt whether I am correct. For the tracks at this place are larger, less divaricate, and the middle toe is longer in proportion to the others than at the Horse Race. I have a single track, also, from the south part of Montague, which I bring under this species, not without a good deal of hesitation. In one respect this species differs from all others; and that is, in the wider spread of the lateral toes; although Plate 45, Fig. 38, is more divaricate than usual; and I suspect more so than is natural.

14. *O. delicatulus.* Toes three, all in front; narrow, middle one nearly straight; a third longer than the others: lateral ones slightly curved towards the middle one; spreading 40°: nearly of equal length. Heel nearly circular; large, distinct. Impression of the toes and heel nearly of equal depth and distinct: of the toes, sharp. Length of the middle toe, an inch and two tenths: of the heel, four tenths of an inch: of the whole foot, an inch and a half. Length of the step, 3 inches. Shown of the natural size, in relief, but too clumsy, on Plate 45, Fig. 40.

This very elegant species occurs at that most prolific locality, the fine red slate at the Cove in Wethersfield; which we might suppose formed a thoroughfare for all the tridactylous and tetradactylous animals of the Connecticut valley, in sandstone days. I have found but few specimens, and yet they are too distinct and peculiar to allow me to refer them to any other species.

15. *O. minimus.* Toes three, all in front; narrow: middle one about a quarter longer than the outer one: a little curved inwards: lateral toes spreading from 70° to 100°; somewhat curved outwards. Heel rarely making an impression. Length of the middle toe, from four to nine tenths of an inch. Length of the step, usually 3 inches. Shown of the largest size, on Plate 45, Fig. 41. On Plate 42, Fig. 30, is exhibited a number of tracks of this species, some of them very small.

This species occurs at several localities: but perhaps most abundantly at Wethersfield, on the red slate. Plate 45, Fig. 41, was obtained at that place; and shows two successive tracks most distinctly: one of which is turned a little towards the right, and the other towards the left. Plate 42, Fig. 30, was sketched from a slab obtained in the north part of South Hadley, of gray micaceous sandstone. Some of these tracks are much smaller than this species usually is; and two of this description I have no doubt are tracks in succession. Tracks equally small occur at the Horse Race in Gill, and some of the usual size. It is an elegant little species, and truly, when compared with the enormous O. giganteus and ingens, it deserves the name of O. minimus.

16. *O. tetradactylus.* Toes four, three of them in front: middle one about a third longer than the others: nearly straight: lateral toes spreading from 60° to 80°: curving slightly outwards toward their tips: fourth toe proceeding from the inner side of the foot, and running obliquely backwards, so as to form a prolongation of the outer lateral toe: sometimes slightly curved forwards: length about an inch and a half. Heel rather narrow; short, impressing the stone obliquely behind. Length of the foot, exclusive of the fourth toe, 2.5 to 3.5 inches. Length of the step, 10 to 12 inches? Shown of the natural size on Plate 46, Fig. 42.

Some specimens of this species often arrest the attention more than those of any other, because they so exactly resemble in shape and size the tracks of some domestic fowls; as the common hen and the turkey. But as a species, this track is often more difficult to distinguish

than almost any other, because the fourth or hind toe is so often wanting. On the animal, as is the case with many living species, this toe must have been attached to the tarso-metatarsus, higher upon the foot than the other toes; so that unless the front toes sunk deep into the mud, the hind toe would not reach the ground. Usually, also, such toes slant towards the ground; and hence we often see the impression of their extremity, while a space remains unimpressed, between that point and the junction of the other toes. This fact is often exhibited in fossil footmarks, as well as in those of living birds. Indeed, in the former, so much space sometimes intervenes between the impression of the fourth toe and the heel, that one is in doubt whether that impression may not be the remnant of another track, and not connected with the three front toes near it. However, the fourth toe is pretty uniformly on the line of the outer toe continued backward; and this circumstance will help decide such a case. Yet here we are met with another difficulty. The chief difference between the Ornithoidichnites tetradactylus, and the Sauroidichnites minitans, is that the heel of the latter is longer, and the fourth toe proceeds from a point on the heel farther behind the junction of the other toes, than is the case in the O. tetradactylus. Still, the difference between them is sometimes so small, that I have been led to doubt whether the species be not identical. I conclude upon the whole, that they cannot be; especially as the S. minitans is much larger and stouter in all its proportions. But this near approach of two species, which I have arranged in different families, leads to the inference that probably both families were formed by the same class of animals: or rather, that most of them were. I have been afraid that the terms Sauroidichnites and Ornithoidichnites convey an impression of a greater difference between the tracks than actually exists.

The locality at the Horse Race furnishes not a few specimens of the O. tetradactylus: yet when I obtained them, not having definitely settled the species, I neglected to measure the distance between the tracks, till the surface was broken up. The same was true of the very distinct specimens of this species which I obtained at Wethersfield. Hence none of the drawings of successive steps exhibit this species. I think, although not certain, that I have found it at Chicopee Falls.

17. *O. gracilior.* Toes four: three in front: slender: middle one less than a quarter longer than the two others; straight: lateral ones spreading from 60° to 90°; usually as much as 80°: considerably curved outward: nearly of equal length: inner one rather shortest. Heel scarcely visible behind the point of junction of the toes. Fourth toe on the inside of the foot, and on the prolongation backward of the outer toe: impression deepest at its extremity: generally failing altogether a part of the distance between the extremity and the heel. Length of the foot, exclusive of the hind toe, from an inch and a half to two inches. Length of the hind toe, nearly an inch. Shown of the natural size on Plate 46, Fig. 43.

I am not certain that I have found this species any where except at Wethersfield. It a good deal resembles the O. tetradactylus in form: but it is a far smaller, more slender, and delicate species. My best characterized specimens are always more divaricate than the O. tetradactylus; and in stating the divarication of the lateral toes, as between 60° and 90°, I embraced several specimens in which the hind toe was wanting: but which otherwise resembled the O. gracilior; and therefore I place them here; because I know not where else to refer them. They would come nearest to O. tenuis: but the middl ϵ toe is too short, and the heel too narrow; and as the fourth toe is very often wanting in the tetradactylous species, I do not regard its presence as

essential. In some specimens, it made an impression not more than a quarter of an inch long, but very distinct; and at the distance of nearly an inch from the heel. It is not a common species; and I did not notice its peculiarities till I had left the locality; so that I am unable to state the length of the step. I have one specimen, indeed, which I regard as this species; although wanting in the fourth toe, in which two tracks appear to be in succession, and only three inches apart. If this was the step of the animal, I judge from the analogy of the steps of the other species, that this must have been a good deal shorter than the usual step, and hence do not use it in description. This species is an elegant one, and exceedingly resembles the tracks of some slender toed Grallæ of the present day, upon the muddy shores of ponds and rivers.

## *Summary of Species.*

The following Table will bring under a glance of the eye, some of the most important facts respecting the various species of footmarks that have now been described. The linear measures are all in inches.

| SAUROIDICHNITES. | No. of Toes. | Divarication of the lateral Toes. | Length of the Middle Toe. | Length of the Foot. | Length of the Step. | Ratio of the Length of the Middle Toe to that of the Step. | Ratio of the length of the foot to that of the step. |
|---|---|---|---|---|---|---|---|
| 1. S. Barrattii, | 5 | | 3 | 5 | 11 to 14 | 4.2 | 2.5 |
| 2. heteroclitus, | 4 | | 1.25 | 2.25 | | | |
| 3. Jacksoni, | 4 ? | | 1. | 2.5 | | | |
| 4. Emmonsii, | 4 | 50° | 2 to 3 | 2.5. to 3.5 | | | |
| 5. Baileyi, | 4 ? | 30° to 40° | 3 to 4 | 3.5 to 5 | | | |
| 6. minitans, | 4 | 60° to 80° | 3 to 4.25 | 6 to 7 | 15 to 17 | 4.4 | 2.5 |
| 7. longipes, | 4 | 70° to 80° | 3 to 3 5 | 5 to 9 | 15 to 17 | 4.9 | 2.3 |
| 8. tenuissimus, | 4 | | 4 | 4 | | | |
| 9. palmatus, | 4 | | 2,25 | 2.5 to 3 | 8 | 3.6 | 2.9 |
| 10. polemarchius, | 4 | 40° | 10. | 14 | 48 | 4 8 | 3.4 |
| ORNITHOIDICHNITES. | | | | | | | |
| 1. O. giganteus, | 3 | 40° | 13 | 17 | 48 to 72 | 4.6 | 3 5 |
| 2. tuberosus, | 3 | 25° to 35° | 5 to 6.5 | 7 to 8.5 | 18 to 33 | 4,5 | 3 3 |
| 3. expansus, | 3 | 50° to 70° | 4.5 to 5 | 6 to 7 | 25 | 5.2 | 3.8 |
| 4. cuneatus, | 3 | 60° to 75° | 2 5 | 3.5 to 4.5 | 8 to 12 | 4,0 | 2.5 |
| 5. parvulus, | 3 | 30° | 0.5 to 0.8 | 0.75 to 1.25 | 5(?) | 7.0 | 5.0 |
| 6. ingens, | 3 | 50° to 60° | 15 to 16 | 23 to 25 | 40 to 72 | 3.6 | 2.3 |
| 7. elegans, | 3 | 60° | 4.5 to 6 | 6 to 7 | 12 to 21 | 3.2 | 2 5 |
| 8. elegantior, | 3 | 70° | 2 to 2.5 | 3.5 | 5.5 to 9 | 3.2 | 2.1 |
| 9. Deanii, | 3 | 60° to 70° | 2.5 to 3 | 4 to 4.5 | 9 to 12 | 3.8 | 2.5 |
| 10. tenuis, | 3 | 50° to 60° | 2 | 2.75 | 7 (?) | 3.5 | 2.5 |
| 11. macrodactylus, | 3 | 40° to 55° | 4.5 to 4.7 | 5 to 6 | 15 to 21 | | |
| 12. divaricatus, | 3 | 75° to 85° | 4 to 6 | 4 to 6 | 4 | 3.6 | 3.6 |
| 13. isodactylus, | 3 | 90° to 120° | 1.5 to 2 | 1 5 to 2 | 3 (?) | 2.3 | 2.3 |
| 14. delicatulus, | 3 | 40° | 1.2 | 1.5 | 3 | 2.5 | 2.0 |
| 15. minimus, | 3 | 70° to 100° | 0.4 to 0.9 | 0.4 to 0.9 | 10 to 12 (?) | 4.6 | 4.6 |
| 16. tetradactylus, | 4 | 60° to 80° | 2.3 to 3,3 | 2.5 to 3 5 | | 3,9 | 3.7 |
| 17. gracilior. | 4 | 60° to 90° | 1.5 to 2 | 1.5 to 2 | | | |

The two last columns in the above Table were obtained by dividing the mean length of the step by the length of the middle toe for the first, and by the length of the foot for the last And the approximation to equality in the ratios thus obtained, (with the exception of the O. parvulus, the length of whose step is very uncertain,) is an interesting result; especially when it is recollected that the length of the step in several instances, was made out from only one or two examples. It will justify the conclusion, that *the length of the step increases directly as the length of the foot.* This conclusion is very important; because it shows us that we are correct in supposing the present size of the different tracks to be the actual size of the feet that made them: and because it proves that the same accurate relations existed between the parts of animals in

ancient times, which now exist. The ratio between the length of the foot and of the step in the preceding Table, is not mathematically the same. But it does not differ more than it would, were we to compare together the feet and the steps of 20 species of living animals: as I am confident from a careful examination of such tracks for several years past.

## *Tracks in Succession.*

In giving an account of different species of fossile footmarks, I have described I believe all the drawings accompanying this Report of these tracks in succession. But as this constitutes an important part of the subject, I shall here briefly recapitulate those descriptions, in order to call particular attention to the Plates. In most cases these were copied directly from the stones, either at the quarries, or in my Cabinet: and it is intended that they should give an exact representation of the surface of the stones containing them. To exhibit, however, on so small a scale, all the peculiarities of the tracks was impossible; and therefore only their prevailing form is given. When deficient in some part upon the stone, that part is omitted. They are all laid down from the same scale, viz. a half inch to the foot.

Plate 48, Fig 44: A slab in my Cabinet, 20 by 30 inches, showing two rows of S. Barrattii, and one of O. parvulus.

Plate 48, Fig. 45: A slab in the Cabinet of Dr. Barratt of Middletown, showing two rows of S. Barrattii, one row of five tracks of O. cuneatus, two rows of O. tuberosus, and two insulated tracks.

Plate 48, Fig. 46: A surface 5 feet by 3 feet, as it lay in the quarry at Wethersfield, showing numerous tracks of the S. Emmonsii, mixed with those of S. Baileyi. At the time the sketch was taken, however, I did not distinguish between these species: nor did I represent all the tracks upon the slab. But as the surface was soon after broken up, the painter was obliged to take my imperfect sketch for his guide. The principal use which I would make of this drawing, is to show that the two species of animals that made these tracks, were gregarious. It is not accurate enough to draw any inferences from it as to the tracks which are connected, or as to the length of the step, which I unfortunately omitted to notice.

Plate 48, Fig. 47: This sketch shows eight tracks of S. minitans, which was most distinctly exhibited in a quarry on the north side of Chicopee river, a little east of the village of Cabotville. Another track undoubtedly existed between the first and second; but the rock there was broken away deeper than the surface generally. The length of this surface is nearly 10 feet; but it is somewhat reduced upon the drawing. This fine example has been subsequently destroyed.

Plate 48, Fig. 48, shows a single row of S. longipes in Wethersfield, now broken up.

Plate 47, Fig. 49, shows five rows of O. giganteus, and at least three rows of O. tuberosus and expansus, with some insulated tracks, on a large surface in Northampton on the bank of Connecticut river. These tracks are a good deal worn by long exposure and by floods; but they still remain essentially as when sketched: and I could wish that I had the power to preserve it from collectors of specimens and quarrymen. The former, I am sure, cannot obtain specimens there, which, when insulated, will be of any use; because too indistinct for the Cabinet.

Plate 48, Fig. 53, is a sketch of numerous tracks of O tuberosus, expansus and giganteus, almost without order, although careful observation on the spot enables one to connect successive tracks: as for instance, the three of O giganteus upon the drawing. In the same vicinity surfaces considerably larger than this, (which is 11 feet long and 6 feet wide,) are literally covered with tracks, so interfering with one another as to render it difficult often to make out the entire track; and so uneven as to ruin the slab for a flagstone. The locality is in the southeast part of Northampton.

Plate 48, Fig. 50, shows an analogous case from Gill: the tracks are those of O. tuberosus and expansus. Originally the slab was a good deal larger. It is in my Cabinet.

Plate 48, Fig. 52, exhibits two very distinct rows of O. tuberosus, considerably different in size, proceeding in opposite directions. These tracks are almost exactly upon a right line: from which I infer that the animal had quite long legs; as such bipeds now make similar tracks. The locality is in the southeast part of Northampton. This fine example is now nearly destroyed by the inroads of collectors, in the vain effort to obtain Cabinet specimens.

Plate 48, Fig. 54, was sketched from a large door stone in Wethersfield, and exhibits two rows and a few insulated tracks, of O. tuberosus. The length of the slab is 9 feet, and its width five feet. The length of the step is from 21 to 24 inches. The tracks follow one another almost in a right line.

Plate 48, Fig. 55, presents a row of 4 tracks of O. cuneatus, from the north part of South Hadley. Another track is said formerly to have belonged to it, which was broken off. There is an indistinct row of tracks on the stone, not shown on the drawing, of another species, probably S. Barrattii. The slab is in my Cabinet.

Plate 49, Fig. 56. This is a sketch of four tracks of a small variety of O. ingens, taken from the rock at the Horse Race in Gill. But it has been already described sufficiently.

Plate 48, Figs. 57, 58, 59, 60, 61, 62, show slabs of O. elegans; all, except the two first, being in my Cabinet. These have all been sufficiently described.

Plate 48, Figs. 63, 64, are slabs in my Cabinet from Northampton, exhibiting several rows of O. divaricatus. But these also have been fully described.

I might have added other examples of tracks in succession: but I suppose it unnecessary: for I have given all the important varieties.

## *Specimens of Doubtful Origin.*

I have found at Wethersfield a few specimens of apparent impressions, upon a hard slightly reddish stone, about which I am much in doubt. At first view they appear as if the mud that formed the rock had been so thoroughly trodden over by animals, that the individual tracks are lost, although the whole surface is covered with irregular indentations.

Another specimen bears some resemblance to the two toed tracks, which Dr. Cotta supposes he has lately found upon the new red sandstone in Saxony; which are described in the American Journal of Science, Vol. 38, p. 255. But without wishing to throw any doubt over his discovery, I have not evidence enough that those which I have found are of organic origin, to describe them as such. I have not seen the specimens in place; but on one of the fragments, a distinct depressed Ornithoidichnites occurs upon the surface opposite to that on which the peculiar impressions above described occur. Hence they must have been formed by the mud folding over some irregularities of the surface on which it was deposited. In some instances, also, I notice a sort of overlapping of the elevated parts of the rock, as if the mud, when plastic, had been pushed forward after it had received an impression. In short, there is some appearance of a concretionary structure in the fold of the mud: and to that agency, in connection with some inequalities of surface, I should refer them. But they are certainly quite singular.

## 4. *I shall now present some collateral facts, connected, as will appear in the sequel, with the conclusions respecting the fossil footmarks.*

### 1. *Impressions of Rain Drops.*

Among the specimens obtained by me at Wethersfield, was one, about whose origin I formed no

opinion until I saw a description of the impressions of rain drops, in connection with tracks of the Chirotherium, on the new red sandstone near Liverpool in England. This description so exactly corresponded to my specimens, that I could not hesitate to regard them as of the same nature as those in England. At the Storeton quarry in England, "the under surface of two strata, at the depth of 32 or 35 feet from the top of the quarry, presents a remarkably blistered or watery appearance, being densely covered by minute hemispheres of the same substance as the sandstone. These projections are casts in relief of indentations in the upper surface of a thin subjacent bed of clay, and due, in Mr. Cunningham's opinion, to drops of rain." (*Lond. and Ed. Philos. Magazine*, 1839.)

I have not seen the specimens from England: but it is difficult to examine those from Wethersfield with this idea of Mr. Cunningham in mind, and not feel that the supposition most exactly satisfies the state of the phenomena. To apply another test, however, I brought a surface of clayey mud into a plastic state, such as it would assume by the overflowing of water, and then sprinkled water upon it. The impressions made were almost exactly like those upon the stone. In general, however, they were rather larger than those upon the stone, unless I took care to divide the water into very fine drops. There was also another circumstance, which I could not well imitate. In many cases, the impressions on the stone are perfect hemispheres, considerably flattened. But sometimes they are elongated in a particular direction, as if the drops of rain struck the mud obliquely; just as they would do when accompanied by a strong wind. In England this same circumstance has been noticed, and very probably explained, by supposing the rain attended by wind. On this supposition it is easy to ascertain in what direction the wind blew at the time. By examining two layers of rock at Wethersfield, containing the rain drops, which were separated by a stratum about half an inch thick, I found that in one case the wind was northwest, and in the other southwest. These showers must have been separated by an interval of at least a year, to allow so much rock to accumulate as lies between the layers that are impressed; and probably it was several years.

I think we may push these conclusions a little farther, and infer that where we find the impressions of the separate drops, the rain must have been only a slight shower, and not a continued storm. For much repetition of the drops upon the same surface, must have obliterated all traces of separate drops, and produced only a confused impression. If I mistake not, I have specimens which show this work in different stages. We have first, an enlargement of the drops: as if more than one had fallen in nearly the same spot. These depressions continue to enlarge until the surface of the stone presents an appearance not much unlike that of a *chopped sea*. The irregular ridges are very sharp, and the shallow cavities are from a quarter of an inch to an inch in diameter, often elongated to twice that distance. In one instance slight ripple marks appear to have partially obliterated the traces of the rain.

On a re-examination of the locality at Wethersfield, I find that the rain drops are confined to no one particular layer of the rock; but occur on several layers, which are interstratified with those on which the footmarks are found. This fact has an important bearing upon our reasoning as to the situation of the surface when the footmarks were made. But this will be shown more fully in the sequel. I will only say here, that I have introduced in this place a description of the impressions of the rain drops, because it forms an element in solving the problem of the footmarks.

On Plate 49, Fig. 65, I have endeavored to give an idea of a specimen of the impressions made by the rain drops. A much better idea, however, can be obtained by examining the specimens deposited in the State collection. Such an examination will satisfy any one, I think, that there is great plausibility in the theory that has been explained. And if that be indeed true, it affords a curious illustration of the manner in which the minutest events may sometimes be recalled from the remotest antiquity, by geological researches. No geologist will venture to say

how many years have elapsed since the deposition of the new red sandstone. But no one will begin to estimate that period by cycles less than ten or twenty thousand years; and most would at least double and treble those cycles, perhaps several times. And yet, here we have as perfectly preserved as if made yesterday, the traces of a shower that fell at that remote epoch! Nay, we see as distinctly as if registered by an anemoscope, the direction of the wind; and the petrified surface too, tells us, as infallibly as a pluviameter, the quantity of rain that fell!

## 2. *Fossil Bones in the New Red Sandstone.*

For the same reason that led me to describe the impressions of rain drops in this connection, I introduce here a description of some curious fossil bones that have been discovered in the sandstone of the Connecticut valley. I have alluded to them in another place; but deferred a full description of them to this part of my Report.

About 20 years ago, the bones of an animal five feet long, were found in a reddish coarse sandstone or conglomerate, near Ketch's Mills in the east part of East Windsor in Connecticut, two or three miles east of the Connecticut river. They were found in blasting a well, at the depth of 23 feet from the surface of the soil, and 18 feet from the surface of the rock. The animal was described to me as lying in a horizontal position; and at one extremity a series of vertebræ projected 18 inches beyond the body of the skeleton. A fragment of one of these vertebræ I obtained, although the greater part of the specimens were distributed among visitors and are now lost. Professor Silliman, however, has succeeded in recovering several fragments, and has been so kind as to allow me to sketch such of them as are perfect enough to be of use in determining the nature of the animal. They are shown on Plate 49, Figs. 66, 67, 68.

A remarkable fact respecting these bones, is, that they do not appear to be at all mineralized. They have the whiteness of bones that have been burnt, and probably most of the animal matter is gone. They are very brittle, and on exposure to the air, are easily crumbled to pieces. But the fact to which I wish to call particular attention, is, that most of them appear to have been hollow bones; and the cavities are now filled by the sandstone, not different at all, (except perhaps in being a little finer,) from the rock that surrounds them. This is shown upon the drawings, which are of the natural size. Fig. 68 is obviously a part of a vertebra. The others I pretend not to refer to any particular place in the animal system. It will be seen, especially from Fig. 66, that the bony matter must have been very thin around the cavity. Fig. 67 is equally so: but its oblique position brings more of the surface into sight.

Still more remarkable specimens, for which I am also indebted to Prof. Silliman, are shown on Plate 46, Figs. 69, 70, 71, 72, 73, of the natural size. These are made up entirely of fine reddish sand; and yet, their resemblance to bones is too obvious to be mistaken. Figs. 69, 70, and 71, are evidently condyles; and Figs. 72 and 73, which are the same specimen shown in different positions, are obviously a rib. I have met with only one description of an analogous specimen. Dr. Buckland in his Bridgwater Treatise, (*Vol.* 1, *p.* 236, *English Edition*,) describes a specimen in the Museum at Oxford, from the Wealden Formation, which "presents the curious fact, which is perhaps unique amongst organic remains, of a perfect cast of the interior of a large bone, apparently the femur of a Megalosaurus, exhibiting the exact forms and ramifications of the marrow, whilst the bone itself has entirely perished. The substance of this cast is fine sand cemented by oxide of iron." Can it be that the specimens under consideration are of the same nature? The hollow character of the bones shown on Plate 49, Figs 66, 67, 68, certainly favors this idea: but whether the cavity of the bones of any animals that have hollow bones, (not a mere medullary cavity,) extends into the condyle so far as these must have done, I am unable to say. If it does, the sand might have entered at the other extremity, where the bones

appear to have been fractured; as was the case described by Dr. Buckland: and the bone must have subsequently decayed, so as to leave a cast of its cavity.

These specimens were presented to Professor Silliman by a son of Hon. John Hall, of Ellington; a town that adjoins East Windsor. In answer to my enquiries, Judge Hall informs me, by letter, that the specimens were found at two places in Ellington; neither of which is more than 2 1-2 miles from the locality already described in East Windsor. One of them was in a bowlder upon his own farm. A single bone (for Mr. Hall describes it as a real bone and not a cast,) was obtained there, which the workmen nearly ruined in getting it out. He vaguely estimates that the animal to which it belonged, may have been as large as an ox. At the other locality, which is a quarry the bone, supposed by the workmen to be a rib, as large as that of a middling sized dog, was found, 3 or 4 feet beneath the surface. Judge Hall's statements, therefore, and they are probably the most accurate that can now be obtained, do not throw much light upon the casts said to have been brought from Ellington: for in his description he does not make any distinction between real bones and casts; or rather, he calls all the specimens bones. It would be very desirable, if it be not now too late, that a definite account of these singular relics should be obtained. In the sequel I shall point out the bearings of the facts above stated upon the present subject of enquiry:—I mean the fossil footmarks. None of these have been found, I believe, either in East Windsor or Ellington. Yet the layers of rock in which the bones were found, probably lie only a few feet above those containing tracks at Springfield, Wethersfield, and Chatham prolonged And therefore, the bones and the footmarks may have proceeded from the same animals.

## 3. *Tracks of Living Animals.*

Who would a priori have thought it could be of any use to devote himself to the study and description of the footmarks of animals upon snow and mud? Yet how valuable would such knowledge have been to me, in solving the interesting problem which I have undertaken! But a resort to libraries in this case was vain: and therefore, I have been compelled to resort to observation. Nor has the subject proved one to be so easily mastered as at first view might be imagined. The principal points of enquiry, to which I have directed my attention, have been two. First, to ascertain what living animals form footmarks most nearly resembling those in a fossil state; and secondly, how do the tracks of a quadruped differ from those of a biped? In prosecuting these enquiries, I have traversed the muddy shores of our ponds and rivers, during the warmer seasons of the year, and watched the winter haunts of animals, that I might see their tracks upon the snow. I have also resorted to the larger museums of our country, and obtained leave to examine and take copies of the feet of animals from other climates and continents. I would acknowledge my particular obligation to Mr. St. John, proprietor of the American Museum in New York, and to Mr. Peale, owner of another valuable Museum in the same city. The results of my examinations are chiefly embodied in Plates 50 and 51, which I now proceed to describe.

Plate 49, Fig 74, is given in addition, and represents the successive tracks of a small snipe of the natural size, upon the mud on the shore of Connecticut river. The mud had become so hardened by the sun that I have been able to preserve the specimen in my cabinet. The principal impression was made by the three front toes: but behind three of the tracks, the extremity of the fourth toe made a slight impression, as if the end of a blunt stick had been pressed upon the mud. The length of the steps varies a good deal, and the course is rather crooked; as if the bird almost stopped and turned a little aside, and then moved faster; just as a snipe frequently does. I infer it to be the track of a snipe, only because of its resemblance, and because it was found precisely where this species abounds.

Plate 50, Figs. 75 to 78, and Fig. 87, afford examples of the successive tracks of several quadrupeds and bipeds, which I copied either from mud or snow, where the animals had moved apparently at their usual pace and in a natural manner. Fig. 75, shows the tracks of a wharf rat, (*Mus decumanus*,) copied from the mud, when the tide was out, in Duxbury. The length of the toes, reckoning from the center of the foot, was half an inch, and the distance between successive impressions of the same foot, about twelve inches.

Fig. 76, represents the tracks of a quadruped, copied from the mud on the banks of Connecticut river in Northfield; and I suspect them to have been made by the mink, (*Mustela vison*.) The track is shown of enlarged size on Fig. 90. The fifth toe rarely made an impression; and sometimes only the three longest are seen. The length of the step of the same foot was only about 6 inches, while the foot was about one and a half inch long.

A few tracks of the muskrat (*Fiber zibethecus*,) are shown on Fig. 77, sketched from the mud on the banks of Connecticut river in Deerfield. In this case too, the fifth toe is rarely seen. A single track is shown enlarged on Fig. 91. The length of the step varied from 5 to 8 inches, and that of the foot was one and a half inch.

On Fig. 78, are shown a few steps of the tortoise, whose extent I have not preserved. They give a better idea of the relative situation of the tracks of a quadruped when moving in a regular manner, than the cases before described. They were copied from dry earth.

The tracks of a dog upon snow, are shown in Fig. 79. The diameter of his foot was about 2 inches, and the length of the step varied from 10 to 13 inches. A part of these tracks appear as if made by a biped: that is, they are nearly equidistant, and there is only one row. This is not an uncommon appearance in the tracks of a dog, and I am told by hunters, still more common in those of the fox. How the animal produces such tracks I can hardly conceive; though I know that the dog has the habit often of using only three legs when running, and he often brings the hind foot so exactly into the track made by the fore foot, that only one impression remains. I suspect that the appearance under consideration is produced by a combination of these two things.

The only other tracks of a quadruped which I have sketched, are those of a mouse on snow, shown on Fig. 87. The foot was about half an inch in diameter, and the length of the step from 3 to 4 inches. I apprehend the movement was by leaps.

These examples are sufficient to illustrate the movements of quadrupeds. On Fig. 80, are seen the successive tracks of the common partridge or ruffled grous, (*Tetrao umbellus*.) The length of the foot, exclusive of the hind toe, is two inches; and that of the step, from 4 to 5 inches. The fourth or hind toe, it will be seen, reached the ground only near its extremity. The impression of this toe is almost exactly on a prolongation backward of the outward toe.

Fig. 81, exhibits a few tracks of the common domestic goose, (*Anas anser*,) copied from the mud. The length of the foot is four inches, and of the step, seven inches. The impression of the web is usually quite obvious; but on very stiff mud I have sometimes seen no trace of it. The tracks deviate more from a right line than those of any biped which I have met, in consequence of the great width of the body of the goose, and the shortness of its legs. The lateral toes are also exceedingly divaricate.

On Fig. 82, is shown a row of tracks made by the common domestic hen, (*Phasianus gallus*,) on mud. The foot, exclusive of the hind toe, is nearly 3 inches long; and the length of the step, 6 inches. Only the alternate tracks showed the hind toe, which is apparently a prolongation backward of the outer front toe. The tracks are usually almost upon a right line, unless the animal changes its course.

A few tracks of the *peahen*, (*Pavo cristatus*,) are shown on Fig. 83, copied from moist snow. Length of the foot, exclusive of the hind toe, 3.5 inches: of the step, 9 inches. The tracks are in a right line, and the hind toe is situated as in the domestic hen. In these tracks, as well

as in those of the domestic hen, the impression of a small heel was obvious at the center, from which all the toes radiated. The same is the case in the next species.

This is the common domesticated turkey, (*Meleagris gallipavo,*) whose tracks are shown upon Fig. 84. The length of the foot, (that of a large male,) as impressed upon the snow, was four inches, and of the step 12 inches. The situation of the fourth toe, which is usually present, is the same as in the two last cases.

But in Fig. 85, is shown a row of tracks made on dry soil, by a bird of which I caught only a glimpse, but which resembled the quail: and in these the hind toe seems to be merely a continuation backward of the middle front toe. The length of the middle toe, exclusive of the hind one, was an inch and a half; and of the step, 5 inches. The tracks varied a little from a right line.

On Fig. 86, are shown a few tracks of the crow, (*Corvus Americanus,*) copied from the mud. Length of the foot, exclusive of the hind toe, 3 inches: of the hind toe, which extends directly backward, so as to be on the same line as the front toe, one and a half inch: of the step, 6 inches. The track behind is quite wedge shaped, as shown in the figure, and the tracks deviate a good deal from a right line.

## *Single Tracks.*

Fig. 94, represents a single track, probably of the great heron, (*Ardea Herodias,*) copied from the mud, on the banks of Connecticut river in Northfield. The hind toe is upon the same line as the front middle one, and is about an inch and a half long. The length of the whole track, including the hind toe, was 5 inches; and I found others 7 inches long at the same place. The length of the whole step of these larger ones, was 15 inches. The divarication of the lateral toes, which curve backward a good deal towards their tips, is not less than 115°.

The remaining figures, appearing like tracks, are not in fact copied from impressions of the animal's feet, but obtained in a manner that amounts essentially to the same thing. I got leave at the Museums, where dried specimens are placed in the most natural position possible, to put paper beneath their feet, and then traced the form of the foot as exactly as I could. Except that the dried specimens are somewhat shrunk and the divarication of the toes may not be exactly natural, I do not see why such a sketch does not correspond to the track made by the animal. And I apprehend that the exceptions above named, do not much distort it in general.

Fig 88, was traced from the right foot of the South American ostrich. The dotted line at the posterior part shows the form which the track would have, were the animal treading upon yielding mud, in consequence of a knobbed heel, or callus, which does not extend downward quite as far as the rest of the foot. The length of the foot, exclusive of this heel, is 5 inches.

Fig. 89, shows the right foot of the crowned heron, (*Ardea pavonina,*) of South Africa. The hind toe reached the floor only for a short distance near its extremity. Length of the foot, exclusive of the hind toe, 5 inches. It is easy to see upon this drawing two tuberous swellings upon the inner toe, and three upon the middle one, while they are indistinct upon the outer one, though four are visible in the specimen.

Fig. 92, is the left foot of the Cassowary, or New Holland ostrich, (*Struthio casuarius.*) Length of the foot, 5.5 inches.

On Fig. 93, we have the left foot of the Coot, (*Fulica Americana.*) The singular form of its toes is occasioned by a membrane with which they are lined. How far this membrane would make an impression on mud, I am unable to say, having never seen the bird alive: but from the dried specimen I presume it would make an impression. If so, we should have in the track two tuberous swellings on the inner toe, and three in the middle one, while those on the outer toe,

would be indistinct The hind toe is on a line with the front middle one. Length of the foot, exclusive of the hind toe, 5 inches : of the hind toe, an inch and a half.

Plate 51, presents us with still more examples of the feet of animals. Fig. 95, is the right foot of the Horned Screamer, (*Palamedea cornuta,*) of South America. Length of the foot, exclusive of the hind toe, 5.75 inches : including that toe, 9 inches. This is a remarkably large foot for a bird about the size of a turkey; and shows us that the length of the foot alone will not afford a sure index of the size of the animal. Divarication of the lateral toes, 80°.

Fig. 106, was copied from the right foot of the Blue Heron. (*Ardea cærulea.*) Length of the foot, exclusive of the hind toe, 4.5 inches. Length of the hind toe, and the outer lateral one, which are on a line, 6.25 inches. Divarication of the lateral toes, 90.°

Fig. 109, was taken from the right foot of the *Ardea minor*, or *American Bittern.* It differs but little from Fig. 106 : the length of the foot, exclusive of the hind toe, being 4 inches, and of the hind toe and the outer front toe, 5.5 inches. Divarication of the front toes, 60.°

Fig. 108, was taken from the right foot of the Stork. (*Ardea cichonia,*) Length of the foot, exclusive of the hind toe, (which is inserted so high upon the leg as to touch near the extremity only,) 4.5 inches. Divarication, 80.°

Fig. 105, was taken from the right foot of a species of *Charadrius* or Plover. Fig. 104 was copied from the foot of another species of the same genus. They are given on account of their striking resemblance to some of the fossil footmarks. The latter is shown a little web footed. The length of both of them is about an inch and a half. The divarication in Fig. 104, is 60°: in Fig. 105, it is 80.°

Fig. 97, shows the left fore foot, and Fig. 99, the left hind foot, of the Iguana of the West Indies. The length of the former is 4 inches, and of the latter, 6 inches.

The remaining figures on Plate 51, are sketches of the feet and part of the legs of a few bipeds and quadrupeds, mostly copied from well executed engravings. For Fig. 107, however, I am indebted to Dr. Richard Harlan of Philadelphia. It shows the feet, and in one of them the tarsal joint, of the *Charadrius Wilsonius*, a small species of plover, found in our country even as far north as Massachusetts, and belonging to the tribe of waders. The feet are shown of the natural size.

Fig. 98, represents the foot of a species of *Fulica*, or Coot, probably the same species as is shown on Fig. 93, Plate 50. This is added to convey a still more accurate idea of a foot, which must have a strong analogy to some which produced the fossil footmarks.

Fig. 101, is a similar foot of the *Tringa* which belongs to the tribe of Grallae or Waders.

Fig. 102, shows the foot of the *Tetrao lagopus*, a bird of extreme northern regions. It is given partly because it is hairy, and partly because the tarso-metatarsal bone lies in such a position that it must make an impression nearly as deep as the trifid toes.

Fig. 96, exhibits the left hind foot of the *Phyllurus Cuvieri*, a species Gecko lizard, from Port Jackson in New Holland. In the fore foot the five toes all point forward. (*See Dictionnaire Classique d'Histoire Naturelle, Pl.* 120.)

Fig. 103, represents the right hind foot of another lizard, the *Lacerta lemniscata* of Rees' Cyclopedia; and Fig. 100, the left hind foot of the *Lacerta agilis* of the same work. These feet are sketched on account of the peculiar lateral curvature of the toes, and the great length of the heel : also because the fifth toe comes out so far behind the others.

The preceding statements respecting the tracks of living animals, have suggested a few conclusions, which have a bearing upon the subject of the fossil footmarks, and may, therefore, be stated in this place.

In the first place, we learn that the difference between the tracks of quadrupeds and bipeds consists chiefly in two circumstances: first, that the former are arranged in two rows, and the latter in one: secondly, that in the former, there is an alternation of longer and shorter distances

between the successive tracks, at whatever rate the animal moves, while in the latter, the intervals are nearly equal, unless the pace of the animal be altered.

In the second place, we find that some animals, both quadrupeds and bipeds, make an impression with a long heel extending to the tarsal joint, nearly as deep as that with the toes. Consult Plate 51, Figs. 99, 100, 102, 103 and 107.

In the third place, the hind toe, (which is the fifth toe in quadrupeds, and the fourth in bipeds,) sometimes projects so directly behind the foot, that its impression appears like that of a long narrow heel. Consult Figs. 85, 86, 93, 94 of Plate 50, and 96, of Plate 51.

In the fourth place, the fifth or hind toe in some quadrupeds, is situated at different distances behind the others, even to the extremity of the heel, and makes with the direction of the foot various angles. Consult Figs. 96, 100, and 103, Plate 51.

In the fifth place, the fourth toe of birds is usually situated upon a prolongation behind the middle or the outer front toe.

In the sixth place, this hind toe, when not directly behind, is always so situated as to point inwards; that is, towards the line of direction in which the animal moves.

In the seventh place, the toes of some animals would show distinct claws in mud or snow, as in Figs. 89, 93, Plate 50, and 95, 96, 98, 100, 101, 103, Plate 51: but in others they would not be distinguished from the toe, as in Figs. 92, 94, Plate 50, and 107 and 108, Plate 51.

In the eighth place, the toes of some birds would show two distinct protuberances, upon the inner toe, and three upon the middle toe forward of the heel, while those in the outer toe are usually too much blended to be obvious. Consult Figs. 89, 93, Plate 50, and 109, Plate 51.

Finally, the hind toe in birds very often make no impression, or only near its extremity, on account of its situation upon the tarso-metatarsal bone.

### 5. *Conclusions from all the facts.*

Although the terms which I have employed in the preceding descriptions, such as *Ichnolite, Sauroidichnite, Ornithoidichnite,* &c., contain an intimation of the conclusions at which I have arrived on this subject; yet I wish now to present those conclusions in detail, with a summary of the evidence on which they rest.

*In the first place, these impressions are the tracks of animals, made while the materials composing the rock were in a yielding state.*

This is a conclusion that forces itself at once upon almost every one when first examining these impressions. Indeed, I have often heard children short of twelve years old, refer them at once to this origin. This is certainly the first conclusion that is suggested to the mind of any one, who has noticed the tracks of animals upon mud. But because it is the most natural inference, it does not follow that it is the true one; as a multitude of examples in natural history and geology would prove. First impressions are often wrong. Are they so in the present case?

In the first place, all will acknowledge that the rock containing these impressions must have been sand and mud. To prove this to a geologist is

unnecessary; and all others will be satisfied of it, if they will examine it; for they will see that it differs now from sand and mud only in being solid; and by pulverizing it, they can bring it into a state in which it cannot be distinguished from sand and mud.

In the second place, while in a yielding state, if animals had passed over it, the impressions of their feet would have differed in no respect from what the rock now exhibits: and had the yielding materials been suddenly consolidated, tracks upon it could not be distinguished from those which I have described.

Every time I have noticed the tracks of animals upon mud or snow, I have been struck with their resemblance to those on stone: but perhaps never so much so, as when I found the original of Plate 49, Fig. 74, which shows the tracks of a small snipe upon mud. I was examining the impressions on the stone at the quarry at the Horse Race in Gill. The surface of the rock there dips to the south some 30°, and passes directly beneath the waters of Connecticut river. It was late in the summer, and the water was low. But when higher it had left a thin coating of mud on the rock, and the snipes had impressed it as they ran along the margin of the stream. Afterwards, as the season was a dry one, the mud had been subjected to the almost perpendicular rays of the sun, perhaps for several weeks, and had become quite hard; so that I could preserve a specimen. How could I but feel, as I looked at the impressions on stone, and then upon those on the mud, that I had before me an almost complete illustration of the manner in which the former were produced! All that was wanting, was, to have the consolidation of the mud proceed a little farther, and the specimens containing the snipe's tracks, could not be distinguished from the others.

In the third place, these impressions resemble the tracks of animals in their forms. For proof of this, I refer to the drawings and descriptions which I have given, both of these impressions and of the tracks of living animals. More convincing evidence would be obtained by examining the specimens themselves, and observing the tracks of animals upon snow and mud. It is true, there are some peculiarities in a part of these impressions, of which I do not find the exact counterpart in any living animals which I have examined. But were there no such peculiarities, it would in the view of the geologist, be a strong argument against the position which I take. For he finds peculiarities in all other relics of organic nature in early times; some of them, as great size for instance, in races congeneric with those now on the globe, the same as those found in these impressions. But in all their important points, these impressions correspond to the tracks of living animals. The number of toes is three, four, or five; and so it is in living animals. In the position and divarication of the toes, there is an entire corres-

pondence. They show heels of different forms and sizes, as do also living animals. Some of them have distinct claws, whose relative size and situation agree with those of living animals. But I will not here go more into detail.

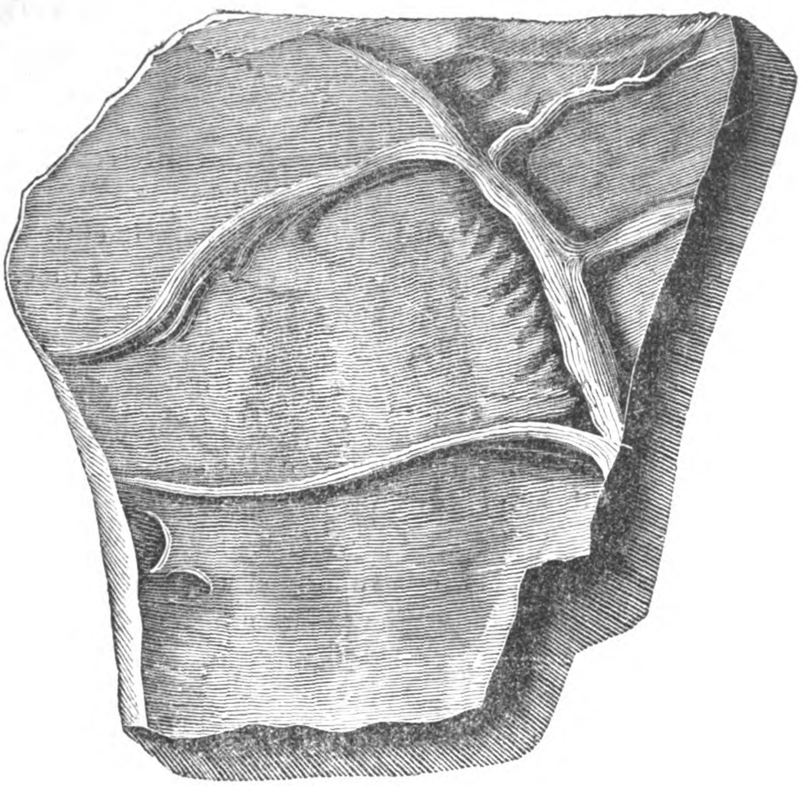
In the fourth place, the manner in which the rock is impressed corresponds to the footmarks of animals. The layers are always bent downwards, as shown in Fig. 104, already described. The impression, therefore, could not have been made by any solid body which remained upon the mud: as I have already shown. But it is precisely such an effect as would result from the tread of an animal's foot.

Finally, no other supposition, which I can imagine, or have heard suggested, corresponds satisfactorily to the facts. Some have supposed that they might be only the divisions of septaria, or other analogous concretions. But it needs only a glance at the Plates which I have given, or if any one thinks these have been distorted by my imagination, it needs only a glance at the specimens, to be convinced that there is scarcely the least resemblance. The divisions of septaria are not trifid; they do not form depressions in the layers of the rock; nor do they occur in regular succession. But it is unnecessary to dwell upon this hypothesis.

There would be rather more plausibility in referring the footmarks to those veins of clay with which some layers of the shale of the new red sandstone formation abound. These run in all directions, and often give the surface a reticulated appearance: and where they intersect one another, I have sometimes seen them trifid, but usually they are bifid, and are wanting in the regularity, the depressed appearance, and succession of occurrence, which characterizes the tracks. Tracks do, indeed, exist among them, though rarely in this country. But in the stone containing the tracks of Chirotherium in Germany, the two appearances are common together; as may be seen on Plate 26, of Dr. Buckland's Bridgwater Treatise. Dr. Buckland has doubtless given the true theory of the origin of these veins, when he says, (*Vol.* 2, *p.* 37, *English Edition*,) "the irregular cylindrical concretions that intersect each other on the surface of this slab, appear to have been formed in cracks, caused by the contraction of a thin bed of green marl, interposed between two deposits of sandstone." I find on examination, that these veins or concretions are connected with, and of the same nature, as the layer of stone above that which contains them. The probability is, that after the deposition of the lower stratum, it was exposed to desiccation; so as to cause it to contract, and thus to become filled with irregular fissures. When a new layer of clay was brought over the surface, it would fill these fissures, and the veins thus produced, would be connected with the deposit above, but would not become manifest until the upper layer was split off. Sometimes from the wearing away of the lower stratum I have seen the veins project and appear exceedingly like a vegetable petrifaction; as shown on Fig 107, copied from a specimen from Wethersfield.

A person at all accustomed to observation, would not confound the footmarks with these veins: for they have scarcely no similar characters. Indeed, forty-nine fiftieths of the specimens of footmarks which I have found, occur upon rock that contains not a trace of the veins.

Fig. 107.



It has been suggested that these impressions, and indeed all the fossil footmarks that have been described in Europe, are only the remains of marine plants, probably fucoids. The tracks are supposed to be the vesicles attached to the net work which forms the frond. But in the first place, although it is possible to conceive, as I have attempted to show in another place, how the vesicle of a fucoid might make a rounded impression in the mud, it is not easy to imagine how it could make that sharp impression so common in the Leptodactyli; whereby the layers of rocks are bent downward almost perpendicularly. In the second place, can it be believed that the vesicles of a sea weed are ever so regular, that they should uniformly occur in threes, fours, or fives, and that too at almost equal intervals, and alternately, along the opposite sides of the frond, so as to give precisely the appearance of right and left feet! Or if this be admitted, how shall those inpressions be explained that follow one another almost exactly in a right line? Finally, in scarcely any case do these impressions occur in connection with any other trace of vegetable relics. The rock, both between the impressions and within them, shows not the least mark of any organic substances. Now how improbable that a fucoid should have existed, at least 30 feet long, capable of sustaining 9 trifid vesicles, 16 inches long, and each so large as to make an impression equal to that of an ox's or an elephant's foot, and yet so frail that not one trace, either of the frond or the vesicles, should remain? Yet all this must

be supposed to explain the nine tracks in succession, of the O. giganteus, which are still visible on the rocks in Northampton, and which are shown on Plate 47, Fig. 49.

*In the second place, these tracks were probably made upon the margin of an estuary, or lake, where the waters experienced considerable changes of level; with intervals between them; and in a climate subject to the alternations of wet and dry seasons.*

I do not expect to establish these positions with entire certainty. But I think the evidence sufficient to make them probable.

That these tracks were impressed in a place not subsequently covered by water, seems to me highly improbable. For at the present time, how soon are the footmarks of animals made upon the surface of the earth, where it is exposed to atmospheric agencies, obliterated, either by wind or rain? We can conceive, however, how they might be preserved if made beneath quiet waters. For neither wind nor rain would then reach them; and ere long the waters might bring over them successive layers of mud, in so quiet a manner that they would be perfectly preserved. And then, as soon as the mud should become consolidated, the work would be done. Very probably some of the tracks might have been formed under these circumstances. But the facts respecting the impressions of rain drops, forbid us to extend this explanation to all the tracks. For the layers of rock containing these impressions, either contain, or are connected with, the tracks. Now we are certain that the rain drops could not have made an impression beneath the water, however shallow. They must have fallen upon a surface which had been recently covered and saturated with water. And I know of no way in which their impressions upon the mud could have been so perfectly preserved as they are, except by being subsequently covered with water, bringing with it a deposit of mud. But it is not easy to conceive how water should flow over a surface thus delicately impressed, while it was yet wet, without effacing the impressions. I have imagined, therefore, that after the rain drops had fallen, the surface might have remained uncovered by water for a considerable time, and exposed to the heat of a powerful sun; whereby it became quite hard, so that when the water at length rose over it, the impressions would remain long enough to be covered by a layer of mud. If we suppose the tracks to have been made under similar circumstances, they, on account of their greater depth, would stand a still better chance of being perfectly preserved. And many of them are so perfect, that it is certain not the least disturbance took place in the mud after they were impressed.

As the climate of N. England is at present, it would be rare to find a time when a dry season should succeed a shower sufficiently long to pro-

duce much induration of the mud. But the records of geology abound with evidences that our northern climates, at the time when the new red sandstone was deposited, were at least tropical, if not ultra-tropical: and of course, there might be alternations of wet and dry seasons. Suppose then, the impressions of the rain drops and tracks were made just at the close of the rainy season. The dry season that followed might accomplish the work.

It may be difficult to conceive how the surface where the impressions were made, should be wet enough to day to bring the mud into a plastic state, and then experience no more overflowing of the water till it had become indurated by the heat of the sun. Let it be imagined, that the valley of Connecticut river was then an estuary, and that the impressions on its shores were made at the season when the tides were becoming daily less and less. This would bring a large surface in the course of a short time into a proper condition for receiving the impressions, and then, if a dry season followed, they might be preserved until the return of spring tides; which would bring in the silt for a new layer of rock.

We might make a similar supposition if the shores were those of a lake, subject to rise and fall by the inundations of the river which fed it: though we must suppose the rains by which the waters were raised, not to reach the place of the impressions, since it would obliterate them. I think, also, that it is easy to conceive how the impressions might have been preserved around the coves and inlets of a river: for there the water, as the stream rose, would flow in so quietly as not to disturb the finest mud; and then it would be charged with that fine mud which is well adapted for filling up without disturbing the impressions. In fact, I am not sure but the shores of a large stream would be the most favorable of all places for their preservation; especially if we suppose them made beneath shallow water.

One fact respecting the situation of the localities of the tracks in this valley, ought perhaps to be mentioned, as having a possible bearing on their preservation. All the localities hitherto discovered, are only a short distance, at the farthest 3 or 4 miles, from trap rocks, and they lie upon the east side of the trap, that is, above it. In Northampton, where the layers for at least 20 feet in thickness abound in tracks, a deposit of tufaceous conglomerate lies only a few feet beneath the tracks, and covers the trap. Now the protrusion of the trap would produce a shore on which animals might tread, and the heat communicated to the sandstone above the trap, might be great enough to produce a rapid induration. It would be interesting to learn the situation of the various localities of tracks recently found in Europe, in respect to rocks of igneous origin.

*In the third place, most of the tracks that have been described, were made by bipeds.*

A quadruped in moving regularly and naturally makes two rows of tracks, and a biped but one row, as I have already shown. Now the tracks under consideration almost universally form but one row. Again, the intervals between the tracks of a quadruped are unequal; a long interval alternating

with a short one. But the fossil footmarks are arranged nearly on a right line, at intervals as nearly equal as those formed by living bipeds.

Nevertheless, there are a few cases which have been described, about which I have some doubt. The first is that of the Sauriodichnites Barrattii. My doubts arise merely from the resemblance of this five toed track, to that of some quadrupeds. Yet so far as we have evidence in this case, from Plate 48, Figs. 44 and 45, it is all in favor of the biped origin of this track. The second case of doubt is that peculiar specimen of S. Baileyi, shown on Plate 32, Fig. 10, where one track overlaps another, just as those of four footed animals frequently do. But here too, all the evidence we have, which is indeed, small, rather goes against my doubts. The third case is that of *Ornithoidichnites parvulus*, where a large and a small track stand side by side. But as I have more fully shown when treating of that species, we know too little as yet concerning it, to come to a full decision. Upon the whole, we have not sufficient evidence to prove that we have yet found the tracks of even one quadruped, among the 27 species that have been described. But we have abundant evidence that most of them were made by bipeds.

*In the fourth place, I infer that most of the tracks that have been described, were made by birds.*

In support of this position, I rely on the following evidence.

1. *The number and position of the toes.* For the present I pass by the Sauroidichnites, and ask attention to the 17 species of Ornithoidichnites. And a comparison of these with the drawings, given on Plates 50, and 51, of the tracks of living animals, must convince any unprejudiced mind that the resemblance between them is almost as perfect as it could be. As a general fact, the toes on the feet of living birds, that point forward, are three: and they are the same on all these fossil footmarks. Moreover, the divarication of these toes in the fossil specimens, varies about as much, and is about the same, as in the feet of living birds. When the fourth toe exists in living birds, it usually lies either on a prolongation of the middle or outer toe backwards; and so it does in the tracks on stone. But sometimes the hind toe is wanting in living birds, and so it is in most of the Ornithoidichnites. So far as I have observed, I should say that the curvatures in the toes is rather more obvious in the fossil than in the living specimens. Yet it is not always wanting in the latter.

Now among living animals, birds are the only ones that have such feet as have been described. If then we form an opinion respecting the fossil footmarks from the analogies of living animals, we must infer them to have been made by birds, or give up all confidence in the principles of comparative anatomy, which have been shown to be little less certain than the principles of mathematics. If we cannot depend upon the analogy of nature in this

case; that is, if we may not assume the constancy of nature in all periods, then we can form no opinion of past from present events: and a large part of physical science falls to the ground.

2. *The claws and tubercles of the toes.* It is only in the Pachydactyli that the claws are readily distinguished from the other part of the toes. But the same is true in the tracks of living birds, for a reason that has been already explained. The acumination of the toe in all cases, however, renders it almost certain that a claw was always present, as it is in living species. The relative length of the claws, moreover, in the fossil specimens, corresponds very well with its length in living birds. Here then is another point of analogy.

A curious coincidence exists, also, if I mistake not, in respect to the number of tuberous expansions on the toes of the Pachydactyli. I have already stated that there are two of these on the inner lateral toe, and three on the middle toe, and that the outer toe contains a still larger number, but they are indistinct. My belief is, that these tubercles correspond to the number of articulations in the toes. Now Baron Cuvier says, that "birds are the only class (of animals) in which the toes are all different as to the number of their articulations, and where this number is fixed in each toe, as well as the order of the toes. The thumb (*pouce,*) (hind toe,) has two: the first inner toe, three: the middle toe, four: and the outer one, five. This rule has but one exception, that of birds which are wanting in the hind toe: but the other toes have the ordinary number." (*Ossemens Fossiles, Tome Troisieme, p.* 308, *Troisieme Edition.*)

A little reflection will enable any one to see that the tuberose swellings on the toes of the fossil footmarks, correspond to this statement, if we suppose them made by the joints. For take the inner lateral toe, and the articulation of the ungual bone with the second phalanx, will form one protuberance; and the articulation of the first and second phalanges, another. The articulation of the first phalanx with the tarso-metatarsus will form another: but I have not included this joint in the description which I have given of these protuberances. As the middle toe of birds has one more articulation than the inner lateral one, we are not surprised to find the same increase of protuberances in the middle toe of the fossil footmarks, if they were produced by birds. Nor is it strange that the impressions of the joints in the outer lateral toe should be so blended as to be indistinct, if they were as numerous as the articulations in the corresponding toe of birds.

Several of the reptiles, however, have the same number of articulations in their toes as birds, as far as the first four toes are concerned. And as the crocodile has but four toes behind, (*Cuvier's Regne Animal, Tome II. p.* 18.) there will be a perfect correspondence between these and the toes of birds in

respect to the articulations. But as all the other lizards have five toes upon all their feet, (except the Seps and one or two other genera of the Scinoidians, which sometimes are tridactylous, but with feet so small and so situated that it is needless to spend time in comparing them with the fossil footmarks,) and are quadrupeds, we may be confident that the fossil footmarks were made by different animals. But the protuberances upon the toes correspond with no other class except birds.

This argument is not so satisfactory as some others, because I may be mistaken in the nature and number of the protuberances upon the fossil footmarks. But after much careful examination, I feel more and more confident that the preceding statements and reasonings are correct.

3. *The character of the heel.* It is well known to the comparative anatomist, that in adult birds, as a class, the tarsus and metatarsus are united in a single bone, which is not the case with any other class of animals. (*Ossemens Fossiles, Tome Troisieme, p.* 308. *Troisieme Edition.*) Hence the whole lower part of what is usually called the leg of birds is the metatarsus, or perhaps more properly a tarso-metatarsus: at its lower extremity, there is a process shaped like a pulley, for the articulation of the toes.

It is in consequence of this structure of the foot, that the tracks of most living birds show so little heel. Unless the impression be deep, indeed, the toes only are seen, and all the weight appears to have rested upon them. Sometimes, however, as may be seen on some of the figures of Plate 50, an impression is made at the point from which the toes radiate, which results from the lower extremity of the tarso-metatarsus. In one instance at least, that of the South American Ostrich, (*Struthio rhea,*) a process or callus exists behind the toes, which does not extend downward as far as the toes; and therefore, could not make an impression unless the animal sunk deep into the mud.

A large proportion of the Ornithoidichnites correspond to this description as to the heel. Several of them show nothing but the toes: but some exhibit a heel like that of the South American Ostrich, which did not sink as deep into the mud as the toes. As to the nature of the heel of the Pachydactyli, I do not feel entirely satisfied: but I think nothing more can be made of it than the broad termination of a stout tarso-metatarsus, with the processes necessary for the articulations of the toes. The process connecting with the outer toe is peculiarly prominent, and extends back farther than the two others; and this gives to several species (the *O. tuberosus, expansus and cuneatus,*) such a wedge shaped appearance.

There is one exception to the fact stated above, as to the feet of living birds, viz that the tarsus and metatarsus form but one bone. In a few of the web footed species, (the *Palmipedes,*) as the Penguin and the Manchots, the tarsus and metatarsus consist of three bones, and this renders such birds plantigrade; that is, they walk upon the tarso-metatarsus, as well as the toes: In other words, they have a heel extending to the tarsal joint, which is sometimes considerably long. In some species of the Linnean genus Colymbus, a fourth toe is articulated to the tarsus, some distance behind the other toes.

The feet of such birds present the strongest analogy of any with which I am acquainted, to those which produced the Sauroidichnites. The birds, however, are web-footed, and the fossil footmarks show no evidence of such an appendage. Again, the remarkable curvature of the toes in several species, has nothing analogous to it in the feet of the Palmipedes. Further, in one of the species (*S. palmatus,*) we have four toes directed forward, and in another (*S. Barrattii,*) we have five. These tracks, so far as the curvature of the toes, the length of the heel, and the

situation of the hind toe are concerned, certainly correspond in appearance more nearly to the feet of certain reptiles, examples of which are given on Plate 51, Figs. 97, 99, 100 and 103. And it was on account of this resemblance, that I denominated these tracks, *Sauroidichnites*. But I did not thereby mean to convey the impression that I believe them to have been made by Saurians. For to such an opinion there exist two very strong objections. In the first place, with two exceptions, (*S. Barrattii and palmatus*, and the latter is hardly an exception,) they have only three toes directed forward and one behind: and secondly, so far as the evidence goes, they were made by bipeds. Now in these two respects, which are of far more importance than the characters which ally them to Saurians, they correspond to the tracks of birds. My conclusion, therefore, is, that they were made by what may be called *Sauroid Birds:* that is, by birds that approached Saurians in character: just as certain fishes, that existed in the ancient world, and had a Sauroid type, have been called *Sauroid Fishes*, although they are still regarded as real fishes. And it is not unfrequently the case, as we approach the limits between two classes of animals, that we find species on opposite sides of the separating line having many characters in common, yet preserving their distinctive characteristics.

A writer in the *Bibliotheque Universelle De Geneve*, for May 1836, in view of the facts which I gave in the American Journal of Science in relation to our fossil footmarks, suggests whether they might not be *biped Saurians*. I have no objection to this view, if it can be sustained consistently with the principles of comparative anatomy. But if we admit these animals to have been Saurians, we must admit that they had but two legs, and these much longer than those of existing Saurians of the same size: otherwise their steps could not have been so long. Of course, two such long legs could not sustain a body shaped like our present Saurians, but only a body like that of birds. Hence these animals would not be adapted to the haunts and mode of life of any existing Saurians, but to those of birds: and, therefore, it seems to me, the sure laws of relation lead us to conclude that they must have been birds. I know, indeed, that the Pterodactyle approaches the form of birds: and I had hoped to make out that at least some of the fossil footmarks were made by these singular animals; since they probably had the power of moving on two feet. But here we are met by the difficulty, that the toes of this reptile were four, all directed forward, which corresponds only with the S. palmatus. It may be, that as the Pterodactyle approaches as near as possible to a bird, and yet retains the essential characteristics of a Saurian, so the animals that formed the Sauroidichnites, might have come as near to Saurians as was possible, and still be birds.

I confess, however, that in regard to some of the Sauroidichnites, I do not feel any great confidence that these conclusions are correct. I regret that I have not been able to obtain more facts in respect to them, especially as to the successive steps. Not improbably farther research might remove them into the class of Saurians.

4. *The manner in which the tracks succeed one another.* I have exhibited upon Plates 47, 48, 49, 50, and 51, so many examples of these tracks, as well as those of living animals, as they appear upon the rocks, mud, and snow; and have given so minute a description of them, that I need only refer to them in this place. It will be seen that the fossil tracks exhibit the closest resemblance to those of living birds. Some of them follow one another almost upon a right line: and so do the tracks of the peahen, the turkey, and the domestic hen, on Plate 50, Figs. 82, 83, and 84. Others are placed more or less to the right and the left of a right line, and alternately to the right and the left, and so are those of the domestic goose, the quail, and

the crow, on Plate 50, Figs. 81, 85, and 86. If we find in the fossil specimens a track or two removed much more than usual to the right or the left, as if the animal stepped aside, so it is in the tracks of living birds, as shown on Plate 49, Fig. 74, and Plate 50, Fig. 80. If the hind toe in the fossil specimens, when it does not point directly backwards, is always on the inside of the foot, and frequently does not make an impression, or only with the extremity of the toe, so it is in the tracks of living birds; as may be seen on Plate 50, Figs. 80, 82, and 83. In short, I know of no circumstance connected with the succession of tracks in the fossil specimens, that has not its counterpart in those of living birds. But with every other class of animals there is an almost total disagreement in this respect. Why then, should we hesitate to admit that those on stone were made by birds?

5. *The ratio between the length of the foot and that of the step.* I apprehend that this ratio in the fossil specimens agrees better with that of birds than of any other animals. But I do not however, lay much stress upon the argument. For as it did not suggest itself to my mind till recently, I have not made that extensive collection of facts that would be desirable. I give only the few in my possession, derived chiefly from the statements already made of the tracks of living quadrupeds and bipeds.

*Living Birds.*

| | *Length of Foot.* | *Length of Step.* | *Ratio.* |
|---|---|---|---|
| African Ostrich, | 9 inches. | 30 inches. | 3.3 |
| Ardea Herodias, | 5 " | 15 " | 3.0 |
| * Ardea Canadensis, | 3 " | 5 " | 1.7 |
| Turkey, | 4 " | 12 " | 3.0 |
| Peahen, | 3.5 " | 9 " | 2.6 |
| Partridge, | 2 " | 4.5 " | 2.2 |
| Goose, | 4 " | 7 " | 1.8 |
| Domestic Hen, | 3 " | 6 " | 2 0 |
| Quail, | 1.5 " | 5 " | 3.3 |
| Crow, | 3 " | 6 " | 2.0 |

*Quadrupeds.*

| | | | |
|---|---|---|---|
| Dog, | 2 " | 11.5 " | 5.75 |
| Muskrat, | 1.5 " | 6.5 " | 4 33 |
| Mink, | 1.5 " | 6. " | 4 00 |
| Mouse, | 0.5 " | 3.5 " | 7.00 |
| Wharf Rat, | 0.5 " | 12. " | 24.00 |
| Horse, | 5 " | 84. " | 16.80 |

The length of the step in the quadruped, is reckoned from one impression to the next of the same foot. If the distance between the nearest tracks be regarded as the length of the step, and perhaps it ought to be, it would make the ratio more nearly the same in the quadrupeds and bipeds. Still it would not agree as well with that of the fossil footmarks as does that of the living birds.

* I am indebted for the facts in respect to this bird, to Dr. Richard Harlan, of Philadelphia.

6. *A considerable proportion of the fossil footmarks corresponds more nearly with the feet and tracks of Grallæ, or Waders, than any other family of birds.* This is obvious from two facts: first, a large proportion of the Ornithoidichnites have but three toes; which is frequent among the Grallæ: and secondly, the length of the step in these footmarks is usually greater, in proportion to the size of the foot, than in living birds of other families: as an examination of the tables of the length of the foot and step in the fossil and living species, will show. Now if it be admitted, as I have supposed it necessary to admit, that the fossil footmarks were made upon the shores of an estuary, a lake, or a river, we should expect that the tracks of the Grallæ would be most apt to be found in such a place: and the coincidence between probability and fact affords a presumption in favor of the general theory, and of the supposition that the tracks were chiefly made by birds.

It is not necessary, however, from what we know of the habits of living birds, to suppose that all these tracks were made by Grallæ; for birds of prey are very frequently found on the shores of bodies of water in search of food; and the shape of the feet of some of the Sauroidichnites, especially, indicates birds with talons well adapted for assaulting other animals.

7. *The character of the bones found fossil in the new red sandstone of the Connecticut valley.* It is true, none of these bones have been found in immediate connection with the footmarks. But as they occur only a few miles from some of the localities, and in the same continuous formation, if they could be shown to be the bones of birds, I feel as if it would strongly corroborate my theory: for it would at least prove that birds existed during the period when the tracks were made. Now it is well known that the bones of birds are hollow; forming often a very thin cylinder. And from the appearance of those found fossil, at East Windsor and Ellington, which have been already fully described, I have been led strongly to suspect that such was their character. In Plate 49, Figs. 66 and 67, the bony matter is certainly very thin; and if the sandstone condyles in Figs. 69, 70, and 71, Plate 46, once actually occupied the cavity of a real condyle, and the sandstone rib on Figs. 72 and 73, the cavity of a real rib, the original bones must have been hollow to a remarkable extent. But I make no pretensions to a knowledge of comparative anatomy; and shall not, therefore, undertake to decide this question. To do this requires some one extensively acquainted with the bones of different animals. And I had hoped that ere this time these specimens would have fallen under the eye of some distinguished comparative anatomist. But as they have not, I can only figure and describe them, and leave it to others to settle their nature.

Although, therefore, some of the preceding arguments to prove the fossil footmarks to be the tracks of birds, will need farther developement, (for instance, the fifth, sixth, and seventh,) before they will be convincing; yet some of the others are so decisive, (as the first, second, and fourth,) that it is difficult to resist their force. Indeed, when I prepared my first account of these impressions for the American Journal of Science, the case appeared to me so plain, that I felt justified in conveying this idea in the very name by which I designated them, viz. *Ornithichnites.* My convictions are none the less strong, after much more extended observations, than they were at first, on this point. Nevertheless, because some gentlemen of intelligence and science have doubted on this subject, I thought the cautious spirit of true philosophy dictated that I should change the name, so as to imply resemblance to birds' tracks, instead of directly asserting them to be such.

Whenever doubts exist, however, respecting the nature of these impressions, I have little expectation that they will be removed, except by an examination of many specimens, and some at least in their native situations. I have strong confidence that usually such an examination will satisfy others, because it has satisfied me; and I was entirely sceptical until I had seen them. This is one of those cases where one glance of the eye will do more to produce conviction, than the most learned and accurate description. I respectfully invite gentlemen, therefore, who feel an interest in this subject, and have doubts concerning my views upon it, to visit my collections, and let me conduct them to one or two localities, especially before they publicly oppose the idea that they are tracks, or bird tracks.

I do not wish to decide this matter at all by authority; but as the opinion of able judges must be considered highly important on such a subject, I trust I may be excused for referring to the published statements of two distinguished foreign geologists; both of whom had previously seen specimens of these tracks, and one of them had visited my collection and some of the localities. I the more willingly quote their opinions, because they are both perfectly familiar with the fossil footmarks, which, within a few years have been discovered in Scotland, England, and Germany; and could, therefore, determine whether those from the Connecticut valley were of the same general character; that is, whether they were really tracks. Dr. Buckland had, indeed, seen only the few specimens with casts, which I forwarded to the London Geological Society, about the time that his Bridgwater Treatise was in the press: but he had not seen the much more perfect specimens which I have since found. Yet in that work he recognizes these footmarks as those of birds, and says, that " they are of the highest interest to the Palaeontologist, as they establish the new fact of the existence of Birds at the early epoch of the New Red Sandstone formation, &c. (*Vol.* 2. *p.* 40. *first English Edition.*)

Dr. Daubeny, another distinguished professor in the University of Oxford, visited the valley of the Connecticut in 1838; and in his *Sketch of the Geology of North America*, published after his return to Europe, I find the following among other remarks, respecting these impressions. " I will only remark," says he, " that having myself visited one of the spots where these tracks have been recognized, and compared the impressions seen on the surface of the stone with the more perfect ones selected by the professor for his own museum at Amherst, I went away, fully impressed with the belief, that they could have been produced in no other way, than by the treading of birds of various sizes upon a soft and plastic material." (p. 20.)

It may seem a matter of small importance to many, whether these tracks be those of birds or not. But not so to the geologist. For up to the year 1836, when I first published an account of the footmarks, no certain evidence had been discovered of the existence of birds in any strata older than the tertiary. About that time Dr. Mantell proved the occurrence of this class of animals in the Wealden Formation, which lies below the chalk, by the discovery of the tarso-metatarsal bone of a wader in the strata of Tilgate Forest, and a few other fragments of bones. (*Geological Transactions*, 2d *Series*, *Vol.* V. *p.* 175.) But if these imprints in the new red sandstone of the Connecticut valley are really the footsteps of birds, it proves to the geol-

ogist that this class of animals existed thousands and even tens of thousands of years earlier than the period in which the Wealden Formation was deposited. Nor is it their mere existence that is thus ascertained: but more than 20 species have left the imprint of their most characteristic organ, the foot. And some of these are most remarkable for their form or size. Truly, the question is one of great interest and importance to the science of geology: and, therefore, it is proper for the votaries of that science to examine it with the most careful scrutiny. I feel entirely confident, for the reasons which I have presented, that the final decision will agree in its essential features with that which I have now made. I wish always to be understood as excepting a few species of the Sauroidichnites; such as the *S. Barrattii, heteroclitus,* &c.: for it would not surprise me if it should be discovered that these were made by quadrupeds: although that they were the tracks of some animal, I regard as a settled point. Nevertheless, in regard to all my conclusions, if it can be shown that I am wrong, most cheerfully will I resign my present opinions. Nor even in such a case, shall I feel that I have labored in vain; since I shall have turned the attention of geologists to a most interesting subject.

I have pointed out fifteen localities of the footmarks along Connecticut river, in the distance of 80 miles: and from these spots I have obtained 27 species, which I suppose must have been made by different species of birds, and that in a large proportion of instances they probably differed generically. Now I do not believe that 15 places of equal extent can be found at present in the valley of the Connecticut, where, in the course of a summer, the tread of as many species of birds can be found. Shall we hence conclude that these animals were more numerous in sandstone days than they are at present? The climate then was doubtless tropical, or ultra-tropical, and, therefore, more favorable to the developement of animal life than at present. It may be, therefore, that birds were more numerous then than they now are. But the facts above stated do not prove it. For the tracks which I have described, were obtained from many different layers of the rock:—from several even at the same locality. Now we cannot suppose that usually more than one layer was deposited during a year; so that the animals which made the tracks may not have been cotemporaries by hundreds, nay thousands, of years. Hence we might expect by examining these different layers, which are now exposed at the quarries, that we should find the tracks of far more animals than by examining 15 places of equal extent during a single year in the same valley. Hence too, we see the reason why different localities differ so much as to species. I know of scarcely any species, except the animal that produced the Ornithoidichnites giganteus, that seems to have flourished during all the periods embraced in the different

localities. Other species may have died out, and new ones come in: but this one seems to have been preserved; and we can hardly doubt but it had the physical power, not only to vindicate its own rights, but to subject other species to its dominion.

I am led by this remark to say something as to the size of the birds that formed the fossil footmaks, especially the larger ones. In respect to almost all the animals discovered in the secondary rocks, it has been found that many of them are larger than those most nearly allied to them now living on the globe. And a mere inspection of some of the enormous tracks that have been described, (as *O. giganteus and ingens, and S. polemarchius*,) satisfies us that the same rule holds true in respect to the birds. Such a powerful impression was sometimes made by these species, as to amaze one. I have already stated that on comparing the O. giganteus with the foot of an African Ostrich—the largest known living bird—(which I did by weighing carefully pieces of paper cut of the size of the feet,) I found the former to be four times the largest. The ostrich weighs from 80 to 100 pounds: and I am sure that it must have required at least four times that weight to have sunk so large a foot so deep as mentioned above, even into very soft mud.

My friend, Professor Snell, has suggested, that if we suppose the ostrich and the bird that formed O. giganteus to be similar, and the surface of the feet to be as 1 to 4, then the linear dimensions would be as 1 to 2, and the solid dimensions as 1 to 8; and the weight, therefore, as 1 to 8. This may be the true principle of comparison: But in the preceding paragraph I assumed that the weight would be as the surface of the foot: which would make them sink equally deep into the mud.

There is another mode in which we may approximate perhaps more nearly to the size of these ancient animals, provided we obtain certain data from living birds with accuracy, and assume that the extinct ones were of the same family; say, in the present case, that they were Grallæ. Suppose now we obtain the length of the whole leg of a species of living waders, and the length of its ordinary walking step. Taking the length of the step for a base, and the length of the leg for the two other sides, we have an isosceles triangle. Now if we have the length of the step of any other bird of the same family, we may suppose an isosceles triangle formed as above, with the same angle at the summit: and hence by proportion we get the length of the leg that made the track. And if we have measured the length of the first bird, or its height above the ground, we can, by direct proportion, obtain the length or height of the unknown bird. And so almost mathematically consistent are the relations between the different parts of animals of the same tribe, that I have not a little confidence in this rule, as likely to afford a result not very distant from the truth, provided the data are well settled; which I acknowledge to be a difficult matter. In the present case, I have been unable from my situation to obtain but very slender data for the problem; and I give the following statements, rather to illustrate the rule, than in the expectation that the results will be of much value.

Professor Mussey, formerly of Dartmouth College, and now of Cincinnati, had the goodness to take a few measurements from the skeleton of a rather large African ostrich in his Museum. He says that "the length of the leg, viz. the distance from the hip joint to the ground, is 4 feet and 1 inch; and the distance of the head from the ground is 7 feet 8 inches. The elevation of the head, it is obvious, must vary with the direction of the axis of the body, which, as the skeleton now stands, is not quite horizontal, but rises a very little anteriorly." The next point was to obtain the length of the ostrich's step when walking naturally. I am jealous of any trials in the common menageries: But I have been informed on good authority, I believe, that a gentleman in New York kept an ostrich for some time, of an ordinary size, in his garden, and that the length of his step ordinarily was 30 inches. This is the only fact of the kind which I have obtained that I have confidence in. And supposing 30 inches to have been the step of Dr. Mussey's

ostrich, (very probably it was somewhat more; for it appears to be rather above the ordinary size,) and following the rule that has been given, we obtain for the length of the legs, and the height of the animals that made some of the Ornithoidichnites, the following numbers. I have selected only those species which appear to me most nearly related to the ostrich, and the length of whose ordinary step is best settled.

| | *Length of the leg.* | *Height of the animal.* |
|---|---|---|
| O. giganteus, | 77 inches. | 148 inches. |
| O. ingens, { smallest specimen, | 64 " | 123 " |
| O. ingens, { largest do. | 115 " | 220 " |
| O. tuberosus, | 40 " | 77 " |
| O. expansus, | 40 " | 77 " |
| O. cuneatus, | 16 " | 31 " |
| O. elegans, | 26 " | 50 " |
| O. isodactylus, | 6.4 " | 12.2 " |
| O. minimus | 4.8 " | 9.2 " |

I have taken the step of O. giganteus at 4 feet, although sometimes it is 6 feet: but this is not usual. The largest specimen of O. ingens, I have measured only at one locality, where it was 6 feet: perhaps this was its running, not its walking step. It makes the animal 18 feet high. But I have less confidence in this result than in the case of O. giganteus, where the animal was a little over 12 feet high. And after viewing its track, I am prepared to believe that this is no exaggeration.

In order to test the rule which I have given above, I applied it to the steps of a few living birds, which have been given on page 518. The Ardea herodias is one of the long legged waders, and carries its head very high. The largest specimens are more than 5 feet high. But this rule, applied to the example in the table, gives 24 inches for the length of the leg, and 46 inches for the height of the bird; falling considerably short of the height given by Wilson in his Ornithology. The same rule, however, applied to the turkey and domestic hen, makes them several inches taller than they usually are. This confirms me in the opinion that this rule must be confined to birds of the same tribe, and that in the case of the long legged tribe, the data, which I have used, do not give too great a height. I measured the length of the leg of an ordinary domestic hen, and found it to be about 7 inches; and the height of her head was about 12 inches. Taking these numbers for data, and we get the following results for several birds:

| | *Length of leg.* | *Height.* |
|---|---|---|
| Tame Turkey, | 14 inches. | 24 inches. |
| Peahen, | 10 " | 17 " |
| Goose, | 8 " | 14 " |
| Quail, | 6 " | 10 " |

These numbers agree much better with the actual height of these birds than if the calculation had been based upon the numbers derived from the ostrich: and the result of the whole, is a conviction, that I have not overrated the size of the birds that formed the fossil footmarks.

Is it not fair, then, to conclude that such were some of the lords paramount in this beautiful valley, in the immensely remote period of the deposition of the new red sandstone? Nor can we suppose that they reigned here alone;

for if a genial climate then exisfed, as their enormous developement proves, we may infer, from what we know of Divine Benevolence, that other gigantic races of animals participated in its blessings: and to sustain them, vegetable nature must have been proportionally prolific. Few relics of these organic natures have survived. But the history of the footmarks should be a caution to geologists, not to infer too hastily the non-existence of animals because their skeletons have perished. The scarcity of organic remains in the new red sandstone, may probably be more owing to something unfavorable to their preservation, than to their not having existed.

With what interest and enthusiasm does the antiquary open and attempt to decipher and arrange the mutilated and imperfect rolls of some ancient papyrus, that has just been brought to light, and whose contents reveal a new and an earlier chapter in a nation's history, or tell of the former existence of some race before unknown! Shall not the geologist be pardoned, if he indulges some of the same feelings, when he discovers and can read, even though imperfectly, archives of far more ancient date, bringing fresh before his mind, races of animals new and peculiar, that tenanted the globe untold ages before man became its possessor? If an event becomes more interesting the farther it is thrown back into the past, geological facts must surely in this respect take the precedence of all others. For the most ancient event in chronology—the six days of creation—is, I had almost said, the most recent in geology. From thence we wander back through a duration which we can measure only by a succession of events, and not by chronological cycles, except to ascertain from existing nature that the intervening periods must have been vastly long. Then, too, the records which the geologist digs from the rocks, of animal and vegetable existence at immensely remote periods, are often as fresh as if entombed yesterday. Their most delicate parts —even the eye in some instances—are as perfect as when the animal was alive, and the footmarks which he sees following one another in regular succession, are as distinct as those of living animals passing over the mud or the snow before his eyes: while the pattering of a shower, that fell on the same surface thousands of ages ago, is as fresh before him, as if every drop had been instantly petrified.

How many millions of men have spent their days, and finally sacrificed their lives, in order to leave some memento of their labors that would go down to posterity: and yet, not a vestige of their existence remains upon the earth! But the birds and reptiles that passed over the surface, long before the globe was fit for the residence of man, have left marks of their transit, which can never be effaced.* The proudest monuments of human

* See Dr. Buckland's Bridgwater Treatise, Vol. 1, p. 262, English Edition, where the moral of this subject is beautifully exhibited.

art will moulder down and disappear; but as long as there are eyes to behold them, the sandstone of the Connecticut valley will never cease to remind future generations of the gigantic races that passed over it, when yet in a half formed state.

> Birds, a problem ye have solved,
> Man never has:—to leave a trace on earth
> Too deep for time and fate to wear away.

## *Artesian Well in the New Red Sandstone.*

Several years ago, Mr. Disbrow made an exploration by boring for coal in the north part of South Hadley, on the north bank of a small stream running into Connecticut river, on the farm of Chauncey Hale; commencing a few feet above the stream. I was informed on the spot, that he bored to the depth of 180 feet; and that from nearly that depth, a spring of water rushed up with a good deal of force. It continues to flow with much force at the present time; and in May 1840, I made the following experiments, to ascertain whether the temperature in this spring is higher than the mean temperature of the place.

One method was, to ascertain the mean temperature of the spot by applying a thermometer to some wells, the deepest I could find in the vicinity. I had tried this experiment the year previous, in the latter part of August, and as the ground is sandy and the wells not deep, I was confident the water in them felt the influence of the surface temperature: for it was higher than that of the Artesian well. I therefore chose a time the next year, before the heat had penetrated so deep; and after the effect of the snow of winter had ceased. May 30th, 1840, the result was as follows:

| | |
|---|---|
| Temperature of Lewis B. Fish's well, 19 feet deep, | 48° small. |
| " of Alonzo Lyman's " | 46° large. |
| Mean, | 47° |
| Temperature of the Artesian well, | 52° |

Increase of heat by this experiment, 1 degree for each 36 feet.

By the very accurate observations of my friend and colleague, Professor Snell, the mean temperature at the college in Amherst for 1837, 1838, 1839 and 1840, five miles north of the Artesian well, was 46°.34. This would give an increase of temperature equal to 1 degree for every 32 feet.

The near approximation of these results to each other, and to the mean rate of increase in subterranean temperature in other countries, is rather striking. Yet I am disposed to regard it as accidental. But I think I may safely infer from all the facts, that an increase of heat as we descend into the earth at this place, does occur; and that the rate of increase is not widely different from the rate in other parts of the world. And in the paucity of similar observations in this country, I regard this conclusion as very interesting.

The rock at this well is gray micaceous sandstone and shale, very much resembling those of the coal measures: and they dip southerly from 15° to 20°. On the north lies Mount Holyoke, and the surface rises in that direction: so that the explanation of the strong upward force of the water at this well, is perfectly satisfactory, by principles which will be more fully explained in the last part of my Report.

## *Theoretical Considerations relating to the Formation Generally.*

The new red sandstone series that has been described, consisting chiefly of the fragments of older rocks from the surrounding region, must obviously have been produced chiefly by the agency of currents of water, which first wore away these rocks, and then transported and deposited the fragments where we now find them. As to their consolidation we know that water, air, and heat, may all, under certain circumstances, accomplish this work. Water may contain in solution some cement, say carbonate of lime, which shall be deposited in the interstices between water-worn fragments and thus unite them. Air, it is also well known, by abstracting water from some of the materials that form rocks, does sometimes effect their consolidation. Heat, likewise, in the same manner, if it be sufficiently powerful, by producing also a crystalline arrangement of the materials, will harden them into stone. Now in the case of the red sandstone, several of these causes may have conspired to effect its consolidation. The existence of beds of limestone in this formation, and of carbonate of lime diffused through some of the varieties of the shale, and even of the coarse conglomerates, shows that deposition from chemical solution in water, was one of the important agencies concerned in its production. The inclined position of the strata, as well as the character of the organic remains, show that these rocks have been elevated from beneath the water, and of consequence have been, at least in part, hardened by desication. And the presence of trap rocks in the midst of the formation, not to speak of other proofs of igneous action, demonstrates the agency of heat in its consolidation.

It will naturally be inquired, how the red color, so characteristic of the most important varieties of this rock, could have been produced. Undoubtedly it proceeds from the red oxide of iron, which, in some way, has been diffused through the mass. We find in breaking open the fragments in the conglomerates, that the smaller ones are penetrated throughout by this coloring matter; while the larger ones are colored only to a certain depth. (No. 143.) Now, has the iron actually penetrated these nodules, or has heat changed the iron, which they originally contained, into the peroxide? The latter supposition appears to me most probable: and though air and water might possibly produce such a change to some extent, yet I think we must call in the agency of heat, to explain the very thorough manner in which some of the finer sandstones of this group have been colored red. Probably this heat operates upon the materials while yet at the bottom of the ocean. Subsequent chemical changes converting the peroxide of iron into the protoxide, may have produced many of the other colors found in this rock.

Some of the conglomerates of this formation, as that forming the greater part of Mount Toby, in Sunderland, is so coarse, and destitute almost of stratification, that such agencies as now transport detritus are hardly sufficient to account for its accumulation. Very probably powerful disturbances producing deluges, and violent currents, may have assisted in this work.

It is an interesting inquiry, whether the greenstone ranges now existing in the very midst of the sandstone formation, were produced anterior to that rock, or during the same epoch, or afterwards. In all the lower beds of the sandstone formation, I have never found a single fragment of the greenstone; and, therefore, I infer that the latter rock did not exist previous to the deposition of these beds. Nor have I found any of the trap in the conglomerates of the higher beds. It generally separates the higher and more diversified members of the formation from the red thick bedded sandstones and conglomerates of the lower part. Now there is one fact which makes it very probable, that the greater part of the greenstone was protruded immediately after the deposition and consolidation of the lower beds, but before the upper ones were formed—and while

the lower ones were mostly beneath the waters. A deposit of *tufaceous conglomerate* lies immediately above the greenstone, and passes gradually into the sandstones and shales that cover it. The fragments are a good deal rounded, and consist as the cement, does, of a kind of trap tuff and sandstone. It is a rock that must have been formed by the attrition of water upon the materials that compose it, and deposited beneath the waters. Hence the greenstone, as well as the sandstone, must have existed prior to its deposition. Probably, therefore, the greater part of the greenstone may have been poured out over the bottom of the ocean, after the deposition of the lower beds of the sandstone. Then the process of depositing the upper beds commenced: and it would seem that ere long, perhaps before it began, the ridges of greenstone were so elevated above the waters, as to form the western shore. For there we find the fossil footmarks already described, which, as I have endeavored to show, must have been formed upon a muddy shore.

Another fact, which I shall describe when I come to speak of greenstone, shows that that rock continued to be protruded, even after the deposition of the upper beds of the sandstone. For the latter rock, as at Turner's Falls and on Mount Holyoke, has evidently been thrown up at a larger angle, than the usual dip of the rock where it comes in contact with the greenstone. The elevation of the whole formation to its present condition was probably owing to some more general cause, than the protrusion of the greenstone: because the lower and upper beds are elevated together and almost at the same angle.

There is great reason to believe that the new red sandstone formation of the Connecticut valley had a marine origin: that it was deposited beneath salt water. If the fossil plants found in it be some of them fucoides as I have supposed, it would be conclusive proof of this. It is true that the larger part of the vegetable remains in this rock appear as if of terrestrial origin. But these are usually in fragments, showing that they were transported: and probably this valley constituted an estuary making northward from the Atlantic Ocean.

Professors W. B. and H. D. Rogers are of opinion, that the strata of new red sandstone of New Jersey, Pennsylvania, Maryland and Virginia, (denominated by them the Middle Secondary,) assumed their present northwesterly dip, not by being tilted up by a force from beneath, but from the manner of its deposition, which they suppose to have been by currents setting to the northwest and bringing in the detritus of primary rocks. For aught I know this may be a correct supposition. But several circumstances will not allow us to extend this theory to the valley of the Connecticut. The dip of the sandstone there is easterly, or a little southeasterly, so as to bring the strike to coincide with the course of the valley. On each side of the valley is a high range of primary rocks: that on the west being the highest. These ridges were undoubtedly dry land, when the sandstone was in a course of deposition: and therefore the streams running into the valley from these ridges probably furnished the materials for the sandstone. But according to this theory the western ridge must have furnished them all, because the easterly dip extends to the eastern side of the formation. It is scarcely possible that the detritus should have been thus pushed to the very eastern margin of the estuary, while that which must have entered from the eastern primary ridge has left no evidence of its existence. Moreover the dip of the sandstone corresponds to the greater dip of the primary rocks on its western margin: and as we know that the latter have been elevated by a subterranean force, we have here a sufficient cause for the elevation of the latter: I infer, therefore, that the probability is strong that the dip of the sandstone resulted from this cause, and not from deposition on a sloping shore. Besides all this,

I find it difficult to conceive how this formation could have been raised to its present height above the ocean, without being more or less tilted up.

A careful examination of the fossils of this sandstone, will convince any one that their resemblance to any now found living on the globe, is very faint: so that probably they cannot be referred to the same genera, much less to the same species. This accords with the facts that have been observed in other parts of the world. The farther down in the series of rocks we penetrate, the more unlike living animals and plants are those found in a fossil state. And it seems to be now pretty well established, that there have been several successive creations and extinctions of animals and plants on our globe, before the production of its present organized beings. It is not certainly ascertained how many of these destructions and renewals have taken place. Adolphe Brongniart thinks that four changes of this kind are clearly discernible among fossil vegetables.* Hence he infers, that there have been four periods of vegetation since the creation; each differing from the other by a marked distinction in the species, and even genera of plants, and in the numerical proportion of the different kinds. During the first period, the strata, from the lowest fossiliferous rocks to the lower part of the new red sandstone, were deposited. The second period includes the time during which the new red sandstone series was forming. During the third period, the vegetables lived, which are found between the new red sandstone group and the chalk, including the latter. The fourth period commenced after the deposition of the chalk, and reaches to the highest of the tertiary deposits. During each successive period, the vegetation becomes more perfect; that is to say, vascular cryptogamous plants predominated vastly during the earlier periods, while dicotyledonous and monocotyledonous vegetables prevailed during the last period. The same is true in respect to animals. Those found in the lowest rocks are extremely simple in their organization, and vertebral animals, except a few fishes, do not appear lower down than the new red sandstone; while land animals begin to appear still higher in the series.

The conclusions of Dr. Macculloch appear to coincide nearly with those of Brongniart: and the former writer takes animals as well as vegetables into the account. 'Thus then,' says he 'if these views are correct, I have demonstrated four extinctions of antecedent organized creations: while there are two more perhaps less satisfactorily proved.'† He seems to be disposed afterwards to raise this number to seven, or even eight, including man and the existing race of animals.

Sir Charles Bell regards the great difference between the living and the fossil animals, and between those in successive groups of rocks, as decisive evidence of new creations. The principles of comparative anatomy, he considers as proving this beyond all reasonable doubt. 'Every thing,' says he, 'declares the species (of animals) to have its origin in a distinct creation, not in a gradual variation from some original type; and any other hypothesis than that of a new creation of animals suited to the successive changes in the inorganic matter of the globe—the condition of the water, atmosphere and temperature — brings with it only an accumulation of difficulties.'‡

Recent discoveries in astronomy render it probable that there exist disturbing forces among the heavenly bodies; very feeble, indeed, but which must, after periods of immense length, produce important and extensive changes and catastrophes among suns and planets. And one cannot but inquire, whether there may not be some kind of connection between these astronomical and geological periods. But we ought to recollect, in the language of Professor Whewell, that 'our knowledge of the vast periods both geological and astronomical, of which we have spoken, is most slight. It is in fact little more than that such periods exist, that the surface of the earth has, at wide intervals of time, undergone great changes in the disposition of land and water, and

* Dictionnaire D'Histoire Naturelle, Art. Vegetaux fossiles. † System of Geology, Vol. II. p. 432.

‡ The Hand, its Mechanism, &c. p. 115.

in the forms of animal life; and that the motion of the heavenly bodies round the sun are affected, though with inconceivable slowness, by a force which must end by deranging them altogether. It would, therefore, be rash to endeavor to establish any analogy between the periods thus disclosed; but we may observe that they agree in this, that they reduce all things to the general rule of finite duration.'*

It ought not, however, to be forgotten in this connection, that not a few of the disclosures of modern astronomy give us reason to believe, that some of the heavenly bodies are now in that semi-chaotic condition, in which they are unfit residences for such nature as ours, and are in fact in a state similar to that in which the earth was for ages previous to the creation of man; that is, slowly passing from a desolate to a habitable condition. The comets appear to be in the extreme of desolation, even in a gaseous state, demanding periods incalculably long, by the operation of natural laws, for their consolidation, and conversion into fit abodes for animal and rational natures. Possibly still farther removed from such a state, may be the nebulae. The moon appears to be so far redeemed from the uncontrolled violence of volcanos, as to be adapted perhaps to some animal natures. Jupiter is not improbably still covered by a wide ocean, in which such monsters as our secondary strata disclose, may now have sway. In short, astronomy has disclosed enough of the geology of other worlds, to render probable the conjecture, that they are undergoing those astonishing changes, which seem to have taken place, or to be now progressing, within and upon our own.

I am aware that such conclusions as these will seem to many at variance with the sacred record. For Moses speaks only of one creation of plants and animals. But if it be only admitted, as it seems to me the principles of a just interpretation demand, that after mentioning the original production of the universe out of nothing, he leaves untouched an indefinite period, of what may be called the semi-chaotic state of the globe, we shall find no difficulty in reconciling every apparent discrepancy. For during this long period, all those creations and revolutions which the strata now reveal, may have taken place; and the animals and plants thus brought to light, are of exactly the character which we should expect might exist in a semi-chaotic condition of the globe. But of what possible use, in a moral point of view, and in a revelation for the great mass of mankind, would it have been, to have given an account of the creation and extinction of certain huge ferns, sea weeds, zoophytes, and sea monsters, whose relics would be brought to light, not till several thousand years afterwards, by the researches of geologists?

That the first chapter of Genesis admits of the interpretation which I have suggested, is rendered probable from the fact that commentators of no mean name had adopted it long before geologists had suggested the difficulties that have been mentioned. Bishop Patrick, for instance, more than 200 years ago, is full and explicit on the subject in his Commentary. Not a few of the distinguished commentators and theologians of our own days have advanced the same opinion. Suffice it to mention the names of such men as Bishop Horsley, Sumner, and Gleig: Dr. Chalmers, Dr. Buckland, Professors Rossenmuller, Conybeare, Whewell, Jameson, Sir Charles Bell, Sir J. F. W. Herschel, &c.

So far then from finding in these facts and conclusions of geology any objections to the Mosaic records, I find in them a striking evidence of the benevolence of the Deity. For during the long period above spoken of, the globe was evidently preparing for the residence of man, and the other animals that now inhabit it. Before their creation, its temperature was too high, and its surface too liable to be broken up by volcanos and drenched by deluges, to be a secure and happy abode for the more perfect races of animals that now inhabit it. But it was adapted to the nature and habits of such animals and vegetables as we now find entombed in the rocks. The overflowing benevolence of the Deity, therefore, led him to place such beings upon it; and thus to communi-

* Whewell's Bridgwater Treatise, p. 157.

cate a vast amount of happiness, which seems to be a grand object in all his plans and operations. The vegetables that existed in those early periods, have been converted, in the course of time, into the various species of coal now dug from the bowels of the earth; while the remains of the animals of those times have become changed into limestone. And even those violent volcanic agencies, by which the successive races of plants and animals have been suddenly destroyed, have probably introduced into the upper part of the earth's crust, various metallic veins very important to human happiness. And in all this, we see indications of that same benevolent foresight and care, for supplying the wants of his creatures, to which our daily individual experience of God's goodness testifies.

I deduce another moral consideration of no little importance, from the facts and conclusions that have been stated. So constant and uniform are the operations of nature in general, that philosophy has always been prone to regard the universe as a most curious machine, set in motion at the beginning by an all-wise being, who having furnished it with every thing requisite to keep it eternally in play, has left it to run on in the prescribed course, without his interference, and without any need even of his direction and superintendance. Indeed, some have thought this machine so perfect, as to need no creating and superintending Cause, if we only admit it to have been eternally in motion. But these records of geology show us that this supposed uniformity has been often broken in upon. For if the geologist can explain how the operation of natural laws might destroy races of plants and animals, he must admit a special miraculous interference in the creation of new ones. The resemblances between the plants and animals in each of the divisions of the strata, that have been mentioned, even to the very limits of each division, and the suddenness of the change that then takes place in their characters, preclude the idea, so much of a favorite with certain philosophers, that all was the result of a gradual metamorphosis. Now if we thus ascertain that God has specially interfered with the operation of natural laws in the instances under consideration, the presumption is, that he may interfere again, whenever the good of his universe demands. Thus do we get rid of a host of atheistical objections, with which the student of natural theology finds his path encumbered. It would have been well, if some, who can see nothing but atheistical tendencies in the principles of geology, had recollected, before filling their pages with uncandid vituperation of this science and its cultivators,* that it is the only science, with the exception perhaps of astronomy, whose principles could furnish such a refutation.

Nor ought it to be forgotten that these very principles and deductions of geology, that have excited so much of alarm and opposition among some friends of religion, and so much of premature and groundless exultation among its enemies, have nevertheless, when taken in connection with astronomy, developed and established a law of God's natural government of the universe, grand beyond all others known to man; and undiscovered, or only dimly seen, by the great minds of other generations. I refer to the fact, that *perpetual change is made the grand conservative and controlling principle of the universe.* Men have always seen and felt this instability in respect to every thing on earth; and they have regarded it as a defect, rather than a wise law of the natural world. But they now find it to be equally true of suns and planets, as of plants and animals. 'Perpetual change, perpetual progression, increase and diminution, appear to be the rules of the material world, and to prevail without exception.'† And this very instability is the great secret of the permanence and constancy of nature's operations, and of the adaptation of the external world to the wants and happiness of organized beings. It is 'a principle superior to those grand rules which we have been accustomed to regard as constituting exclusively the laws of nature, from the security which we see in it, beyond the longest and apparently most perfect

* See Penn's Comparative Estimate of the Mineral and Mosaical Geologies, 2 Vols. 8vo. 2d Ed. London, 1825.

† Prof. Whewell. Bridgwater Treatise, p. 158.

periodical movements of our solar system."* In fine, it is probably the most splendid display of the Divine skill which the universe can furnish.

I have here entered only upon the limits of a wide field. I cannot proceed farther. The great interest which every reflecting man feels in speculations of this kind, and the expectation of being misunderstood if I entered into no explanation, have led me to venture thus far.†

## 5. Graywacke.

"Graywacke designates," says Humboldt, "when taken in a more general sense, every conglomerate, sandstone and fragmentary or arenaceous rock of transition formation, that is anterior to the red sandstone and coal formation." (*Superposition of Rocks*, p. 201.) "Viewed on the large scale," says De la Beche, "the graywacke series consists of a large stratified mass of arenaceous and slaty rocks, intermingled with patches of limestone, which are often continuous for considerable distances." (*Geological Manual*, p. 433, *Second London Edition.*) In another place he says, that "this group of rocks, as developed in Cornwall, Devon, and West Somerset, (England,) is chiefly composed of sedimentary deposits, varying from the finest roofing slate to conglomerates; some of the component parts of the latter weighing more than half a ton." (*Geological Report on Cornwall, Devon, &c.*, p. 37.)

In my former reports I have supposed that these definitions would embrace a varied deposit of slaty arenaceous and conglomerated structure in the eastern part of Massachusetts; and so it has been considered by all geologists who have written upon the rocks of that region. This conclusion, however, rests chiefly upon their lithological characters. For excepting some coal plants, I am not aware that any organic remains have been found in them. Nor can we resort in this case to relative position to settle the question: for no sedimentary rocks, either newer or older, (except diluvial and alluvial deposits, and a small patch of eocene tertiary,) occur in that part of Massachusetts. However, these rocks are usually much more indurated than those of the coal measures, or the new red sandstone. Indeed, some of them pass insensibly into distinct primary rocks. They are also traversed frequently by veins of quartz; which is scarcely if ever the

* Essai sura Temperature De l'Interior De la Terre. par. M. Cordier, p. 84.

† The connection between geology and the Mosaical record excites at the present day so much interest, and so much crude matter appears on the subject, that I trust I shall be pardoned for referring to those authors who have treated upon it in our own day. In some of the following works, however, such violent prejudices are manifested, and sometimes such deficiency of knowledge, respecting practical geology, that the reader need to be well on his guard in their perusal, and to be thoroughly conversant with the facts of the science.

Cuvier's Theory of the Earth: Conybeare's Introduction to the Geology of England and Wales; De Luc's Letters on the Physical History of the Earth with De la Fitte's illustrations: Penn's Comparative Estimate of the Mineral and Mosaical Geologies: Fairholme's Scriptural Geology: The Mosaical and Mineral Geologies Illustrated and Compared by W. M. Higgins: Bakewell's Geology, with additions by Prof. Silliman, 3d American Edition: Dr. Maculloch's System of Geology: Ure's Geology: Gleig's History of the Bible: Turner's Sacred History: Chalmers Evidences of Christianity: Dr. Buckland's Bridgwater Treatise: Whewell and Bell's Bridgwater Treatises: Knapp's Theology, Vol I.: Bush's Notes on Genesis, with several articles in the London Christian Observer, the Philosophical Magazine, and American Biblical Repository. But especially I would refer to the recent able work of Dr. John Pye Smith on Scripture and Geology, republished in this country.

case, I believe, with rocks above the graywacke. They are also in general highly inclined, and sometimes distinctly interstratified with clay slate. It seems difficult, therefore, to place them in any other series than in that of the graywacke. But in doing this, I mean only that they belong somewhere in the wide space between the carboniferous group and mica slate. This great class of rocks has recently been divided in Europe into a number of distinct groups; and the term graywacke is by many able geologists excluded from the geological series; probably to the advantage of the science. Gladly, were it in my power, would I refer the strata in Massachusetts above described to some of these subdivisions: but I am not able to do it. I do not despair of the accomplishment of this object, when these strata can be examined for a long time by some one properly qualified.

Such were the views which I had entertained of these rocks nearly to the present moment, (January 1841,) when the printing of my Report had proceeded almost to the present page. But a re-examination of my notes and the specimens in the State collection, has suggested some new views on the subject: and I only regret that the season of the year does not allow me to revisit some of the localities, to test them more thoroughly than I can now do. I am now inclined to believe that the graywacke of Massachusetts may be divided into three formations: 1. The Coal formation: 2. Old Red Sandstone: 3. Graywacke. I feel the most confidence in the existence of the coal measures; and in an economical point of view this is the most important point. But as the Tabular View of our rocks has been already printed, I shall not undertake to describe the coal measures and the old red sandstone, except as varieties of graywacke: since this course will produce less confusion; and also because I feel too little confidence in my new views to give them a more prominent place. It happens, however, not to be too late to introduce the Coal formation upon the Geological Map. (Plate 52.) This I have done in those places where I feel confident it exists. Farther examination may detect it in other parts of the Graywacke Group.

The reasons that have led me to adopt the views just suggested, are the following. 1. By examining the Geological Map, (Plate 52,) it will be seen that the principal deposit of Anthracite Coal in Massachusetts, viz. in Mansfield, Wrentham, and Foxborough, and also that in Cumberland, Rhode Island, (which is probably only a prolongation of the deposit in Massachusetts,) lies near the northwestern border of the graywacke basin of Bristol County. Now by a reference to Plate 53, and to Section C, on Plate 55, it will be seen that the strike of these coal bearing strata is N. E. and S. W., and the dip N. W. Hence they constitute the uppermost members of the formation; and if the lowest members be real graywacke, the highest ones are just in the place where we should expect to find the coal formation. 2. I have never met with any varieties of rock connected with any considerable quantity of anthracite, except shale, and a gray micaceous sandstone; although I have some reason to suppose that a very coarse conglomerate is sometimes interstratified with these. Hence the lithological characters of these coal bearing strata correspond with those of the genuine coal formation. 3. Although the species of fossil plants have not been determined, yet by examining Plates 21, 22, 23, 24, 25, and 27, it will be seen that they correspond strikingly with the plants of the Coal Formation. It is indeed true, that the plants found in the graywacke correspond essentially to those found in the coal measures: and on the continent of Europe beds of anthracite more than 3 feet thick, have been found in this rock. (*De la Beche's Geological Report on Cornwall, Devon, &c.*, p. 132.) But it seems now to be pretty well ascertained, that the vast deposits of anthracite in Pennsylvania belong to the true Coal Formation; and therefore, the presumption is, that similar anthracite with the same fossil plants in Massachusetts belongs to the same place in the series; unless its situation in respect to other strata compels us to place it lower in the scale. And we have seen that the reverse is the fact. 4. The great regularity of the strata of rocks in this country, would lead us to expect that the situation of coal in Massachusetts would be the same as in other parts

of the United States; unless its characters, or the rocks containing it, are very much unlike those of the principal deposits in the country. This is the case with the Worcester coal: but not with that of Bristol County; which differs from that of Pennsylvania chiefly in having a little higher specific gravity. But in Pennsylvania the coal lies above a vast deposit of arenaceous, slaty, and conglomerated mechanical rocks, corresponding in general to the graywacke of Europe. If the Mansfield coal be referred to the same place, we have an entire harmony between this limited deposit and those vast ones occupying many of the middle and western states, and belonging o the older secondary. 5. It is probable that the coal bearing strata on the island of Rhode Island form a sort of basin, or rather a trough: for the strata on each side of the island dip towards each other: and hence Dr. Jackson has represented the coal on a section accompanying his Report on the Geology and Agriculture of Rhode Island, as extending in a basin from one side of the island to the other; although no other evidence than that just mentioned has been obtained on this point. Not improbably also, the coal beds of Mansfield and Wrentham occupy a similar position. But the near proximity of these beds to masses of granite, whereby the strata have been greatly disturbed, renders it very difficult to determine this point.

The old Red Sandstone of Europe is with great difficulty separated from the graywacke: and indeed, beds of similar red sedimentary deposits are interstratified among all the members of the latter rock. In England, however, the old red sandstone is usually classed in the carboniferous group of strata, though said to have distinct organic remains. All agree, however, that it lies immediately below the coal measures; or rather below the carboniferous limestone. Now in Attleborough we find extensive strata of a red conglomerate; hand specimens of which can hardly be distinguished from those of the old red sandstone of England and Germany in my cabinet. This rock is most fully developed in the south west part of the town; and its strike and dip have a general correspondence with those of the coal measures of Mansfield. And by consulting the maps and sections on Plates 52, 53, and 55, it will be seen that this rock must be immediately below the coal measures; although I have never traced the actual junction. Nor do I know how far northeasterly this rock extends. It occurs in Wrentham in extensive strata, which are usually arenaceous and not conglomeritic. They are frequently traversed by numerous veins of quartz; and in fact, seem to be almost converted into red quartz rock. The exact position of this rock in Wrentham, in respect to the coal bearing strata of that place, I have never been able to ascertain.

Now if the coal bearing strata of Mansfield are really the coal measures of the geological scale, we can hardly doubt but that the red conglomerate of Attleborough should be referred to the old red sandstone. True, it seems to differ from the gray conglomerates of the graywacke formation but little, except in color: yet we must not forget that the character of the old red sandstone, according to Professor Phillips, is, that its "color is mostly red, or gray, liable to become red." Where, therefore, to draw the line between the old red sandstone (if it be such,) of Attleborough and the graywacke underlying it, I know not. Indeed it is not impossible but all the gray conglomerates and sandstones of the latter formation may belong to the old red sandstone. Most of these conglomerates are too coarse to be referred to that part of the graywacke or Cambrian system which underlies the Silurian system; if it be true, as Professor Phillips says, that the pebbles of the conglomerate graywacke are always quartz and only half an inch in diameter. (*Phillips' Treatise on Geology, Vol.* 1. *p.* 125.) De la Beche, however, as we have seen, describes very coarse conglomerates as a part of what he denominates graywacke.

There are one or two difficulties in the way of the views that have now been presented. One is that the coal bearing strata of this formation are probably interstratified with the coarse conglomerates. I have not met with any certain example of such alternation: but in Dr. Jackson's Report upon the Geology of Rhode Island, it is stated that at Warwick Neck a coarse pebbly conglomerate overlies the carbonaceous slate. As but very little anthracite has been

found there, however, although coal plants occur, it is possible that this slate may lie below the coal measures. But I think it probable that some of the conglomerates will be found interstratified with the coal bearing strata. Yet it would not follow but that the rocks lying beneath those strata might be old red sandstone and graywacke. Or possibly it may be found that the whole of what I call the graywacke formation, belongs to the coal measures ; and that the resemblance of some of its members to the oldest of the fragmentary rocks, in their crystaline structure and numerous injected veins, might have resulted from their proximity to unstratified rocks. In other words, it may be a *metamorphic coal formation;* or one which has assumed the lithological characters of graywacke by the agency of heat.

The other objection to my views as above given, results from the probability that the coal beds of Mansfield, Cumberland, &c., are not in regular basins, but are merely interstratified with the slates, at a high inclination. I am by no means sure that such will be found to be the fact: for I do not know the relative situation of the red rock, (old red sandstone,) of Wrentham in respect to the coal bearing strata, except that it lies between those strata and the granite. But if it turns out that the coal beds are merely interstratified with the inclined strata, and not arranged in basins or troughs, I do not think we must admit that the strata do not belong to a true coal formation. For surrounded as they are by rocks of igneous origin, they may have been disarranged in almost every conceivable mode: nay, they may have been tossed over; so as to have an inverted dip ; as is sometimes the case with the coal strata in Pennsylvania, according to Professor H. D. Rogers.

These views I acknowledge are somewhat crude. But their important practical bearing leads me to throw them out. And in consistency with them, I shall now include among the varieties of the graywacke formation under consideration, *Coal Measures and Old Red Sandstone;* although aware that they are misplaced if they are indeed rightly named.

## *Lithological Characters.*

1. *Coal Measures.* The only varieties of rock which I can certainly refer to this head, are a slate usually much charged with carbon, sometimes glazed so as to exhibit a highly plumbaginous aspect, and often containing vegetable impressions: and a coarser slaty rock, micaceous and arenaceous, but not conglomeritic. Its color is gray. The layers of the slate are often much contorted. (Nos. 1824, 1845 to 1848.)

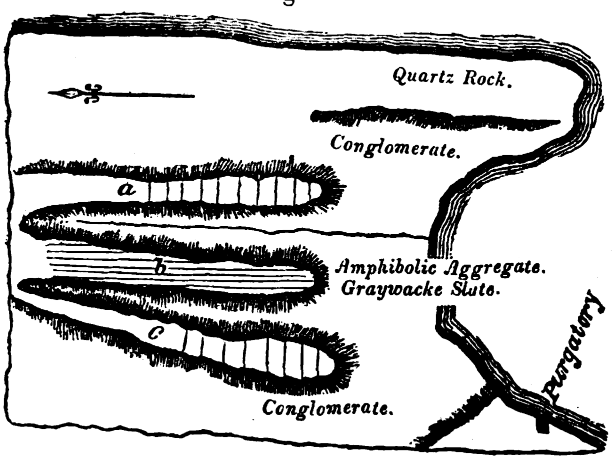
2. *Old Red Sandstone.* There are three varieties which I have referred to this head. The most abundant is a conglomerate made up of fragments of sienite, porphyry, compact feldspar, quartz, &c., cemented by the same materials. The color varies from a dark to a lively red, and the size of the rounded fragments is sometimes several inches. This occurs chiefly in Attleborough; (Nos. 1806, 1808, 1809,) but it is found in other places; as in Walpole. (Nos. 1805, 1811, 1812, 291.) This rock sometimes passes into a variety of so fine a grain, as to form a slate, highly charged with the peroxide of iron, and of a blood red color. (Nos. 344, 345.) In Wrentham, Randolph, &c., we meet with a red quartz rock, often traversed by veins of white quartz, and very much indurated. (Nos. 311, 313, 318, 1820.) This exceedingly resembles a variety of the old Red Sandstone in my possession from Warwickshire, in England. This rock becomes sometimes very slaty and of a chocolate color; (Nos. 316, 317,) and the planes of stratification do not coincide with those of lamination.

3. *Gray Conglomerates.* The rounded nodules in the variety that abounds most throughout the whole extent of the formation, (Nos. 287 to 292, and 307,) particularly in Roxbury, Dorchester, Dighton, Swansey, and Somerset, consist of granite, sienite, compact feldspar, and perhaps hornstone of various colors, porphyry, quartz, argillaceous and flinty slate, novaculite, serpentine, and nephrite. These vary in size from that of a pea to two or three feet in diameter.

The cement appears to be chiefly the same materials in a comminuted state: exhaling, however, an argillaceous odor when breathed upon. Although the imbedded nodules are numerous, yet they have the appearance, as Mr. Maclure describes the older conglomerates, "as if the cement at the time of formation had a consistence sufficient to prevent the particles from touching each other." The cement has generally a semi-crystaline aspect, and adheres very firmly to the nodules. Sometimes the rock is traversed by veins of quartz, which are attached quite strongly to the rock. So thick, and often indistinct, are the strata, that the Messrs. Danas say that "no stratification has been observed in this Graywacke."* But if one traverses the whole formation, he will find abundant examples of this structure; and in most places he will discover it by careful examination; the strata having in general a northerly and easterly dip. This rock is also intersected by numerous cross fissures, more commonly perpendicular to the layers, and remarkable for the exact division which they make of the imbedded nodules; so that one part of the pebble appears on one side of the fissure, and the other part on the opposite side. Veins of trap, also, sometimes traverse this conglomerate; as will be particularly noticed in describing greenstone.

Another very distinct and most remarkable conglomerate occurs at the southeastern extremity of Rhode Island, in Middletown, near Sechuest Beach, three miles east of Newport. (No. 294.) It is composed of elongated rounded nodules of quartz rock, and quartz rock passing into mica slate, with a cement of talcose slate. The nodules vary from the size of a pigeon's egg, to four, and even six feet in their longest diameter, and constitute the great mass of the rock. They are so arranged that their longest diameters are uniformly parallel to one another: lying in a north and south direction: which corresponds with the layers of the schistose cement, and also with the general direction of the strata in the vicinity. Both the nodules and the cement abound in small, distinct, octahedral crystals of magnetic iron ore.

Fig. 108.




The above rough sketch of the southeast point of Rhode Island, will assist in rendering intelligible the relative position of this conglomerate, and also of three or four other varieties of this formation to be hereafter described. About a quarter of a mile from the coast, three precipitous bluffs, *a*, *b*, *c*, several rods wide, separated by salt marshes from 15 to 20 rods wide, rise one or two hundred feet, trending northerly, and converging; so as apparently to unite at no great distance. The two most easterly ridges are very steep, and exhibit evidence of having been pow-

* Mineralogy and Geology of Boston and its vicinity, 1818, p. 94.

erfully abraded. The outer ridges, *a*, *c*, consist of the peculiar conglomerate above described; the central one consists of a hard graywacke slate, and a very singular and puzzling rock, which I shall venture to describe as a metamorphic slate. (No. 371.) Half a mile southeast is an aggregate of quartz and mica to be described in the sequel.

So much of the topography of these rocks, by way of anticipation, seemed necessary in order to explain the peculiar structure of the conglomerate. The layers of the graywacke slate and amphibolic aggregate run north and south, and dip west, from 60° to 70°. And this, as already mentioned, is the direction in which the nodules and schistose layers of the cement of the conglomerate are placed. But no strata planes are to be seen corresponding to the dip and direction of the slate. Yet the conglomerate is divided into horizontal layers, from six to ten feet thick; and also by fissures running east and west, perpendicular to the horizon, and parallel to one another, from 10 to 20 feet apart. These fissures divide the thick masses of conglomerate so perfectly, that they seem as if cut through by the sword of some Titan. The nodules through which the fissure passes, are divided very neatly, and the parts present even surfaces, so as to give the rock quite a peculiar aspect. At the southern extremity of the eastern ramification of the range of hills above described, an immense quantity of the conglomerate has been carried away by former aqueous action, and the present bluff is terminated by a perpendicular wall, exhibiting this bisection of the nodules in a most striking manner. On account of the size, number, and parallel position of these nodules, this singular instance of fracture is much more remarkable than in the variety of conglomerate first described.

No one can view this phenomenon without inquiring immediately into its cause. And it is obvious at first thought, that this division of the strata must have taken place since their perfect consolidation: otherwise the nodules, instead of breaking, would have been drawn out of the paste. Nor could mere desiccation have produced such an effect, for the same reason. Nor does any hypothesis afford to my mind the least satisfaction, except that which supposes these fractures to have resulted from a powerful force, acting at right angles to the meridian, beneath the conglomerate, after its consolidation. And when we find large deposits of granite in the vicinity, we have ascertained the existence of a power adequate to such an effect: although we might resort to the hypothesis of Elie de Beaumont, which has of late excited so much interest, and which imputes most of the fractures and dislocations of the earth's crust to the secular refrigeration of its internal parts, whereby its outward envelope becomes too large and plicated.

Another important fact in respect to the conglomerate under consideration, is the occurrence in it of numerous veins of quartz. Some of them are not less than a foot wide: as in Roxbury, where the Providence Rail Road is cut through a hill of conglomerate; and they are frequently branched. These veins separate the imbedded nodules, and are chemically united to the divided portions.

4. *Breccias.* These are distinguished from the conglomerates by the angular shape of the imbedded fragments. One variety (Nos. 296, 297,) consists of fragments of reddish and ash colored argillaceous slate, united by an argillaceous or an arenaceous cement. This aggregate is slaty, and the cement has a porphyritic appearance. I have observed it only in a few places; as at Natick and Randolph. Another variety, approaching to slaty porphyry, appears to be composed chiefly of compact feldspar, united by a cement of comminuted porphyry. This was found also in Natick. (No. 298.)

As we pass from the range of porphyry and compact feldspar on the south of Boston towards the graywacke, and if I mistake not at the junction of the two rocks, (e. g. in Dorchester and Canton,) we meet with a rock of a peculiar character, whose origin appears to be in part mechanical. The compact feldspar seems to have suffered some degree of abrasion after its consolidation, and the fragments to have been reconsolidated into a rock more or less slaty, with the admixture of but few foreign ingredients. (Nos. 301, 302.) It would seem to have been par-

tially fused the second time; or perhaps it might have been produced by the partial cooling of the compact feldspar at its junction with the graywacke, as it was forced through that rock while in a melted state. This would account for its semi-brecciated aspect and slaty structure, and the occasional presence of foreign ingredients. But this rock deserves a more careful examination than I have been able to give it.

5. *Classical Graywacke*. I mean by this term to designate the rock described by Werner's ablest commentator, Professor Jameson. He says that Graywacke 'is composed of angular or other shaped portions of quartz, feldspar, Lydian stone, and clay slate, connected together by means of a basis or ground of the nature of clay slate, which is often highly impregnated with silica, thus giving to the mass a considerable degree of hardness. The imbedded portions vary in size, but seldom exceed a few inches in breadth and thickness.' Brochant does not include in the term graywacke, any variety of rock 'whose grains exceed the size of a hazle nut.' Hence the conglomerates that have been described above, cannot be regarded as *classical* graywacke. But associated with these conglomerates, we have rocks of a much finer grain, whose composition corresponds essentially with the above definition; (Nos. 324 to 334,) although every ingredient may not in all cases be present. It often becomes fine grained and passes into graywacke slate, as at the quarries in Pawtucket; where it is traversed by numerous veins of quartz mixed with calcareous spar.

6. *Graywacke Slate*. This variety of rock is quite common in this formation. Its colors are either gray or red; and it appears to be composed in a great measure of indurated clay. Mica, however, sometimes enters into its composition. Its structure is always slaty: but the layers are less fissile than those of argillaceous slate, and its aspect more earthy; though it is no easy matter to draw a line between them. It is traversed frequently by veins of quartz. (Nos. 335 to 346.)

7. *Argillaceous Slate*. The argillaceous slate in the eastern part of the State is so intimately connected with the varieties of rock above noticed, that it ought in justice to be described as one of the members of the graywacke group; although marked as a distinct deposit on the Map. And I doubt not but it is older: for fragments of this slate occur in one of the varieties of conglomerate that have been described; and this not only shows the posterior production of the latter, but renders it doubtful whether both rocks were produced during the same geological epoch.

In general its color is dark gray, passing to blue: It is rarely fissile enough to be employed for roofing. The laminæ, as on Rainsford island, in Boston harbor are sometimes very tortuous. Not unfrequently it passes into an imperfect novaculite; as in Charlestown, Roxbury, Weymouth, Newbury, and some of the outer islands in Boston harbor. (Nos. 357 to 370.)

8. *Limestone*. The greatest quantity of limestone associated with the graywacke is in Newport, near Fort Adams. Several beds occur there of considerable size. It forms one of two small islands in the harbor. This rock is compact, almost as hard as quartz, and appears in many places to be almost converted into chert. According to Dr. Jackson's analysisis, it is dolomite; as we might expect from its proximity to granite, and the striking evidence all around of the powerful metamorphic agency of heat. The limestone appears to form beds in the slate.

Small beds of a compact light grey limestone occasion the red sandstone rock in the southwest part of Attleborough. I did not see much of it in place: but from the numerous blocks in the stone walls, I suspect it may exist there in considerable quantity. From its analysis, given on page 80, it appears to be a quite pure carbonate of lime, destitute of magnesia.

In the southwest part of Walpole a much larger bed of gray crystaline limestone occurs, which, from its strike and dip, (S. W. and N. E. dipping N. W. 45,°) I strongly suspect to be connected with the graywacke; although sienite occurs very near it, and no graywacke is visible in the immediate vicinity. The analysis given on page 80 of this limestone, shows it to be destitute of magnesia, although containing a good deal of earthy impurity.

Several other varieties of rock occur in connection with the graywacke: but having evidently undergone great changes by igneous agency, they will be described more appropriately under Metamorphic Slates.

## *Topography of the Graywacke.*

I have anticipated so much of this head, that brevity may now be consulted. It will be seen by the Map that this formation is confined exclusively to the eastern part of Massachusetts and Rhode Island; and that it exists in several detached patches. On the present, which is the fourth edition of the geological Map, I have connected the strip of graywacke passing through Dedham, Walpole and Wrentham, with the broad deposit south of the last named place. Nor should I be surprised, if future observers should discover a connection between the graywacke range in Dedham, Canton, and Randolph, and that in Quincy, Dorchester, &c.: although I failed in finding it. The fact is, this rock in no place rises into anything like mountain ridges; and for the most part, it occupies extensive plains, or gently undulating ground. Diluvium, also is extremely abundant over almost every part of it; so that it is only occasionally, and often at distant intervals, that graywacke is seen in place. This is particularly the case in the most extensive tract of the graywacke, which embraces the greater part of Rhode Island, with nearly every other island in Narraganset Bay, and a strip on the west shore of that bay, as well as a narrow tract on the east shore in Little Compton: and as it extends northerly into Massachusetts, occupies the surface of nearly twenty towns in Bristol and Plymouth counties. In Swansey and Somerset, the most abundant conglomerate of this formation, (which for the sake of distinction I shall call the Roxbury conglomerate, because in that place its characters are strongly developed,) forms several hills of one or two hundred feet in height, producing striking outliers in the landscape. In Dorchester, Roxbury, Newton, Brookline, and Brighton, the hills of the same rock are of moderate elevation; rarely exceeding 200 feet: yet this is the most hilly part of the graywacke formation in Massachusetts. And its low level and the abundance of transported fragments that overspread it, render it extremely difficult to ascertain its limits.

Around Boston the graywacke occupies a basin, of which the Blue Hills form a southern boundary; the porphyry hills of Lynn and Malden a northern, and the greenstone ranges of Weston and Waltham, a western boundary. The argillaceous slate connected with the graywacke, is all found along the northern and southern sides of this basin, as may be seen by the Map. The central parts are occupied by conglomerates and graywacke slate.

I have already suggested the probability that Boston harbor was produced by the wearing away of the graywacke formation. That this series of rocks once occupied the harbor, is obvious from the character of the islands, which are evidently the remnants of a once continuous formation. It is true that these islands are for the most part covered with diluvium: but sometimes on their shores, we find rocks in situ; and in such case I have regarded the whole island as composed of the rock which is thus developed. On this principle, the geological character of the principal islands in this harbor may be set down as follows:

| | | | |
|---|---|---|---|
| Noddle's | Diluvial. | Moon Island—Conglomerate | |
| Castle | | | |
| Thompson's | | Hangman's Island—Sienite | |
| Spectacle Islands | | | |
| Long Island | | Rainsford Islands | Argillaceous Slate |
| Pedock's | | Middle & Outward Brewster | |
| Gallop's | | Boston Light | |
| George's | | Egg Rocks | |
| Lovel's | | Calf Island | |
| Deer Island | | Green's Island | |
| Apple | | Governor's Island | |
| Great Brewster | | | |

It will be seen that argillaceous slate is the predominant rock on the outermost of these islands. In general it is quite hard, and has so little of a slaty structure, that one might well hesitate to call it argillaceous slate. Frequently it appears to be a coarse variety of novaculite. Argillaceous slate likewise appears on the southern side of the promontory of Hull; although the surface is for the most part diluvial.

There can be little doubt that the peninsula of Boston has a foundation of argillaceous slate. This is, indeed, the only rock that has ever been found there in place. And from the occurrence of argillaceous slate in South Boston, and in Charlestown, with a northerly dip in both places, it would be very surprising if any other rock should be found in Boston; unless it were an intruding mass of trap rock. But this slate on the peninsula is buried deep by clay, gravel, and sand. I have colored the peninsula as a diluvial deposit. Artesian wells bored there a few years ago, 260 feet deep, did not reach its bottom.

The only remaining tract of graywacke to be noticed, is one of limited extent, along Parker river in the south part of Newbury, and extending, I believe into Rowley. It consists of gray red and variegated slates, slaty compact feldspar, with talc, and a conglomerate resembling that in Roxbury. Red compact feldspar lies between this rock and the sienite; and some of the nodules of the conglomerate consist of red compact feldspar. A part of this tract I have coloured on the Map, Plate 52, as Metamorphic Slates.

## *Strike and Dip of the Strata.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Swansey, (Conglomerate.) | East and West. | 35 to 40° N. |
| do. do. | N. W. and S. E. | N. E. various. |
| West Bridgewater, (Slate,) | do. | 30° North. |
| North Bridgwater, | do. | Northerly. |
| Canton, | do. | 25 to 50° N. |
| Milton, | do. (nearly,) | 60 to 70° N |
| Newton—north part, | do. | 30° North. |
| Cambridge, | do. | 60 to 70° North. |
| Newbury, (Slate and Conglom.) | East and West, | 45° North. |
| Head of Nantasket Beach, (Conglom.) | E. and W. | North. |
| Berkley, | N. E. and S. W. | N. W. Small. |
| Asonet Neck, Berkley, (Conglom.) | do. | 30 to 40° N. W |
| Newton Upper Falls, (Conglom.) | E. a few degrees N. | North, moderate, |
| do. West part, | E. and W. | do. |
| Attleborough (west part,) | North and South. | East, small. |
| do. (center,) | do. | 50° West. |
| do. S. W. part—Red Conglomerate, (Old Red Sandstone.) | N. E. and S. W. nearly. | N. W. |
| Wrentham, (Red Slate,) S. W. part, | do. | do. large. |
| do. (do.) N. W. part, | do. | do. |
| Natick, S. Village, (Slate,) | do. | do. large. |
| Pawtucket, (Red Slate,) | do. Nearly. | 90° nearly E. |
| do. (Graywacke Slate.) | S. 20° West. | 70° Easterly. |
| Walpole, | N. E. and S. W. | 50° to 60° N. W |
| Cumberland, R. I. Slate (Coal Measures,) | do. | |
| Providence, R. I. and for several miles east. | do. | do. |

| | Strike. | Dip. |
|---|---|---|
| Mansfield, | N. W. and S. E. | 45° N. E. |
| do. (Harris' Mine,) | do. | 30° to 35° N. W. |
| do. (Hardon Mine) | do. | 53° N. W. |
| Portsmouth, R. I. (Slate,) | N. E. and S. W. | N. E. and S. W. |
| From Providence to Warren, Rhode Island. | N. and South. | 45° East. |
| Seekonk, | do. | 10° East. |
| Newport, R. I. near Fort Adams, (Slate,) | N. and S. | 5 to 10° easterly. |
| do. South part, (do.) | E. and West. | Various. |
| do. Southeast part, (do.) | N. and South. | 60 to 70° West. |
| Between Warren and Bristol, R. I. | E. and West | 10 to 20° North. |
| Tiverton Bridge, R. I. (Slate.) | N. and South. | 45° West. |
| Little Compton, (Slate.) | N. E. and S. W. | |
| Watertown, | N. E. and S. W. | 90° |
| Dorchester, (Conglomerate,) | S. E. and N. W. | 15 to 30° N. E. |
| Roxbury, (do.) | do. | do. |
| Natick, (Slate,) | N. E. and S. W. | 45° N. W. |
| Milton, (Argillaceous Slate,) | do. | North, large. |
| South Boston, do. | do. | 50 to 60° N. |
| Nahant, do. | do. | 30 to 40° N. |
| Hull, do. | do. | 60 to 70° N. |
| Rainsford Islands, do. | N. E. and S. W. | Nearly 90° S. E. |
| Charlestown, do. (near the Insane Hospital,) | W. a little N. | 50° S. E. |
| do. do. (in a quarry,) | North and South, | 10° W. |
| do.* do. (Winter Hill,) | East and West, | 15 to 20° N. |
| do.* (Near the Powder House,) | E. and W. Nearly. | 15° N. N. E. |

The predominant direction of the strata in this formation may be seen on the Map, (Plate 53,) which shows the general direction of all the strata in the State. Local exceptions, unless of great extent, cannot of course be shown on a Map of such limited size. These exceptions are so numerous in the preceding table, that one might be disposed to question whether any parallelism in the strike, or uniformity of dip, can be made out. But extensive examination will satisfy any one of the correctness of the Map. I am disposed to believe that this graywacke belongs to two systems of elevation; the one running nearly east and west, and the other nearly northeast and southwest. In the conclusion of my Report, I shall examine this subject more particularly.

It will be seen from the preceding statement of the direction and dip of the strata, that there is much irregularity in the position of the argillaceous slate connected with the graywacke: particularly in Charlestown. But this in general is easy to be explained by the intrusion of masses of greenstone, or the proximity of sienite.

The slaty structure of the slates included under graywacke, does not always coincide with the stratified structure.

In South Boston, and on Rainsford Islands, the argillaceous slate contains divisional planes whereby it is divided, often with great regularity, into tables with rhombic or trapezoidal faces.

* Professor Webster: See Boston Journal of Philosophy, &c. Vol. I. p. 280, et seq.

(Nos. 360, 361.) On Rainsford islands the argillaceous slate, although unusually fissile, is bent so as to form a semicircle within the space of a very few inches. (No. 362.) But in the southern part of Newport, Rhode Island, in the vicinity of granite, we find the most remarkable curvatures in the graywacke slate.

## *Mineral Contents.*

By far the most important mineral in this formation is anthracite coal. But in the first part of my report I have given so full an account of its characters and situation, that I need only refer to that place.

Connected with the limestone of Attleborough, I found good specimens of what appears from its external characters to be petalite; although I have not found time to subject it to analysis. (No. 1837.) This, it is well known, is a rare mineral. In the graywacke of Cumberland I found specimens of a variety of prase: and at the excavations for coal in Wrentham, the sulphuret of iron occurs in numerous cubic crystals, (No. 393.) disseminated through the anthracitous slate.

It is hardly necessary to mention such common and widely disseminated minerals, as crystalized quartz, and calcareous spar. Magnetic iron ore and the micaceous oxide, have also been found in this group in small quantities. In other parts of the globe, graywacke is a repository of gold; and the clay slate connected with it, (transition clay slate,) contains the richest veins of silver in New Spain, according to Baron Humboldt.* But neither of these metals have been found in these rocks in Massachusetts.

Sulphate of baryta is said to occur in Milton: and also fibrous limestone in thin veins in wacke. Adularia and sulphuret of copper have been found also at Brighton. Efflorescent and massive sulphate of iron has been found, according to the Messrs. Danas, on the argillaceous slate in Charlestown.

Dr. Robinson says that the graywacke, near Providence, is traversed by veins of quartz, containing fluor spar.

In Brighton, in the varioloid wacke, I noticed fibres of green asbestus traversing quartz, which by the coloring matter of the asbestus, was converted into prase. (No. 391.)

## *Organic Remains.*

The organic remains of this formation are confined, so far as I know, to the slate connected with what I call the coal formation: and they belong almost exclusively to such plants as are common in coal fields. True, they have been found in Taunton and Raynham, where I have not learnt of any coal having been discovered. But the finer slates of this formation exist there, and the occurrence of the vegetable remains should lead to careful examination for coal, since they usually occur together. I have found no other variety of organic relic in this formation, than those referred to above, except a cylindrical stem in hard dark slate in Attleborough east parish, a mile south of the meeting house, which may be a fucoid. (No. 400.)

De la Beche, in his Geological Manual, mentions the *Pecopteus arguta*, and the *Asterophyllites equisetiformis*, as occurring at the coal mines in Portsmouth, Rhode Island: and Dr. Jackson, in his recent report upon the geology of that State, has figured several other species from that and other localities.

The most prolific localities of these relics in Massachusetts, are Mansfield and Wrentham. They are abundant also in Norton, in the stone walls. As it is very desirable to obtain an ac-

* Superposition of Rocks, p. 105.

curate acquaintance with these, in order to judge of the character of the formation in which they are contained, I have devoted 6 plates, viz. Plate 21, 22, 23, 24, 25, and 27 to their elucidation. I have a few other species not figured: but they are all ferns. Most of those from Mansfield were obtained at the Hardon coal mine; and for many of them I am much indebted to the liberality of General Chandler.

I have examined the large works of Adolph Brongniart, Lindley and Hutton, and Prof. Bronn, on fossil vegetables, but find few of their drawings and descriptions to agree so accurately with those which I have figured, that I can decide as to the species, and sometimes not even as to the genus. Indeed, I have very little confidence in the opinion of any one as to species of fossil vegetables, who has not devoted a long series of years to the subject. Having failed hitherto in obtaining the opinion of such a man upon those in my possession, I shall merely mention the generic name, where it is quite obvious, and omit the species, even where I think I see a strong resemblance. It would indeed throw an aspect of learning over the subject to give specific names: but I prefer to confess my ignorance and not make pretensions which the scientific public know I cannot sustain.

## *Explanation of the Plates.*

Plate 21, Fig. 1. *Neuropteris* on the upper part and a *Sphenopteris* below. Mansfield. On the specimen from which this drawing was taken the fructification on the frond of the Neuropteris is quite distinct. This is a good example of the very perfect manner in which organic relics are sometimes preserved. Fig. 2. *Equisetum* or *Asterophyllites*: Mansfield.

Plate 22, Fig. 1. *Equisetum* or *Asterophyllites*: Mansfield. Fig. 2, *Sphaenophyllum*, Mansfield. This appears almost exactly like the *S emarginatum*, figured in Bronn's *Lethea Geognostica*, Plate VII, Fig. 10.

Plate 22, Fig. 3. Annularia of Sternberg, Mansfield. (Plate VII, Fig. 8 of Bronn's *Lethea Geognostica*.) Fig. 4, *Neuropteris*: Mansfield. Fig. 5, *Pachypteris*? do.

Plate 23. The principal plant upon this plate is perhaps a species of *Pachypteris*, or *Odontopteris*; but I am in great doubt as to its characters. It scarcely shows any veins. It is a large fern, and one of the most common at the Hardon Coal Mine in Mansfield. The same specimen exhibits one or two whorls of the Annularia.

Plate 24, Fig. 1. *Stigmaria*: Wrentham, south part, at an excavation for coal on land of Mr. Guild. The drawing is about half the natural size; and shows the depression on one side, which, according to Lindley and Hutton, is common in the branches of the Stigmaria. Although I traced the stems obliquely across the strata several feet at the excavation, yet the dome shaped center was not uncovered. The cicatrices upon the outside of this specimen, have given rise to the opinion in the vicinity of the locality, that this relic was a huge snake. I have very little doubt that it is a Stigmaria; although I have not found either the central part or the leaves. Fig. 2, shows a specimen of larger size, from the Hardon Coal Mine at Mansfield. This exhibits very distinctly the loose internal eccentric axis, which, according to Lindley and Hutton, is found within the stem.

This singular plant, so common in coal fields, appears to have had a dome shaped center, 3 or 4 feet in diameter, from which proceeded from 9 to 15 horizontal branches, to the distance of 20 or 30 feet; and from these proceeded leaves on all sides, several feet long. The whole plant is supposed to have floated upon water, or trailed in swamps.

Plate 24, Fig. 3. *Calamites*: Mansfield. The drawing is only half the size of the specimen, which is a flattened stem, entirely composed of shale and sulphuret of iron, except that the outside has a highly plumbaginous appearance. The flattening of the stem was occasioned by the position of the plant in the deposit. For where we find them standing at right angles to the

layers they are cylindrical. I found one specimen at Mansfield of this description, whose diameter is 6 1.2 inches.

The Calamites were large, fluted, jointed reeds, with verticillate branches, sometimes at least, around their joints. They are allied to the genus Equisetum, but quite different. And they furnish a good example of the great comparative size of ancient vegetation: for while no living species of Equisetum in New England, or indeed any where else, exceeds half an inch in diameter, those dug from the coal bearing strata of Mansfield, are sometimes more than half a foot thick; which would make the latter more than 200 times larger than the former!

Plate 25, shows by far the most common plant at Mansfield. Fig. 2, exhibits its lower, and Fig. 3, its upper extremity. In appearance it exceedingly resembles a Calamites, with very fine markings and ridges. But it is entirely destitute of articulations; and from the very perfect manner in which it is preserved, I must think that if they existed, I should have discovered them in some of the numerous specimens which I have examined. Adolph Brongniart, in his description of the genus Calamites, says, indeed, *articulationes et sulci externe aliquando vix ac ne vix quidem distincti, in caule decorticato semper manifesti.* Now in the specimens from Mansfield, the furrows, (*sulci,*) although very small, are always exceedingly distinct: while the joints are never seen. And as to a cortical layer, I doubt whether I have ever found one distinct from the body of the plant. Ordinarily a layer of anthracite, so thin as to be little more than a glazing, is all that remains of the plant. I have indeed been led from such specimens as Fig. 1, to suspect that near its base this plant was fleshy and perhaps hollow, so as to make an impression upon the mud when first buried in it, and thus, in the manner already described in respect to the vesicles of a fucoid, to leave that semi-cylindrical appearance exhibited in the figure: for I cannot satisfy myself that there exists a corresponding semi-cylinder so as to form a flattened stem. Upon the whole, had the leaf of some monycotyledonous plant, such as are found upon the grasses, or the pine apple tribe, been enclosed in this rock, it must have produced an impression almost exactly like those shown on Plate 25. They taper towards the bottom in the same manner; although their apex (Fig. 3,) is perhaps a little more rounded. I doubt whether the specimens are ever more than two feet long, and commonly not so much. It is possible that it may be some genus of ferns: but I have met with none in which the veins are longitudinal and parallel like these: although in the Cyclopteris there is an approach to such an arrangement. In short, until some one more familiar with fossil plants shall decide otherwise, I must regard these relics as the remains of monocotyledonous plants. These, it is well known, began to appear upon the globe very early; and if, as is probable, the Stigmaria was dicotyledonous, all presumption against the occurrence of monocotyledons, in the same rock is taken away, even though that at Mansfield should prove to be graywacke instead of a coal formation.

The plants figured on Plate 27, were all obtained at an excavation for coal in the south part of Wrentham on the farm of Mr. Fuller, except Fig. 1, which appears to be a *Sphenopteris* from the Hardon mine in Mansfield, and Fig 5, which is a *Pecopteris* from the same place. Figs. 2 and 3, are quite perfect specimens of *Calamites.* There is one character more strongly marked upon these and upon all the specimens from that spot, than I have seen elsewhere. I refer to the oblique manner in which the articulations cross the stem. I do not know how to explain it, unless it proceeded from the oblique position of the plants as they grew. The shortening of the joints on the lower part of Fig. 2, indicates perhaps that that specimen was the lower part of the stem: but it cannot be so in all the specimens which I have seen, and yet they all show more or less of the peculiarity above named.

Fig. 4, is a single branch of a bipinnate *Neuropteris:* from Wrentham.

Although it would be quite desirable to have the specific characters of the preceding fossil plants determined, yet the statements that have been made of their more general characters, are sufficient to identify them with the plants found in the coal formation in Europe and this coun-

try. The only remaining question to be settled is whether they do not also occur as low down as the graywacke; and I doubt whether a determination of the species would decide, although it might aid in deciding it. I regret that the explorations at Mansfield are suspended; as farther researches would doubtless bring to light many more species. Some others, indeed, are in my possession which I have not figured.

### *Theoretical Considerations.*

That peat, lignite, bituminous coal, anthracite, and plumbago, had a vegetable origin, is now generally admitted. Vegetable matter has only to remain a long time in the earth, under certain circumstances as to temperature and moisture, in order to be converted into bituminous coal: and this, by the agency of heat, certainly may be changed into anthracite. The same agency continued will probably change anthracite into plumbago. Elie de Beaumont has given an example in the Alps, which he thinks proves that "graphite is only a modification of the anthracite," *(Annals des Sciences Naturelles, Tome XV.* (1828,) *p.* 377.*)* The history of the anthracite of this country confirms this view. That this coal in Pennsylvania, Rhode Island, and at Mansfield in Massachusetts, originated in vegetable matter, seems most certain from the great abundance of fossil plants connected with it, and even penetrating through it. But at the two last named localities, this coal appears to have been subjected to a stronger degree of heat from the proximity of igneous rocks, than in Pennsylvania: and accordingly we find but slight traces of plumbago in the anthracite of Pennsylvania. But in that of Portsmouth and Mansfield, it is abundant. Still more striking is this change in the coal bed at Worcester; which occurs in a rock passing into mica slate, and entirely destitute of organic remains. Here, nearly one half of the carbonaceous matter appears to be plumbago; and has been used for it as I have stated elswhere. Some have even supposed that the diamond may have a vegetable origin.

As to the manner in which such vast accumulations of vegetable matter as are necessary to produce coal beds have been made, there is some diversity of opinion among geologists. That the plants grew mostly on dry land all will admit. But some suppose that these have been drifted from their place of growth into estuaries, by inundations, and then covered by deposits of mud: though no geologist supposes they would have been carried far from their place of growth. But others, as Lindley and Hulton, in their Fossil Flora, conceive it to be "highly improbable that any considerable part of plants which formed the beds of coal were drifted at all;" because their most delicate parts are preserved. They and others suppose that the plants were imbedded on the spot where they grew: or rather, that the land was submerg-

ed and the plants buried by a deposit of mud. It seems to me an almost insuperable objection to this view of the subject, that coal fields often contain 50 or 60 beds of coal, separated by strata of shale and sandstone: and hence, for every bed of coal, the spot must have been raised above the waters long enough for the plants to grow, which might produce the coal, and then have been sunk again to receive a deposit of mud and sand. Of these numerous elevations and submersions we find no trace; and it seems to me we are, therefore, driven to adopt the other hypothesis. Probably in the case under consideration, the plants that produced the coal of Massachusetts and Rhode Island, grew upon the primary regions around its present place of deposit.

It is an interesting thought, that the eastern part of Massachusetts was once covered with a dense tropical vegetation. For the plants disinterred with the coal of Mansfield, are of a tropical character; as they are in every other coal field in northen regions, even as far north as Melville island. And they were also of gigantic size compared with the present races. Yet it seems probable that no land animals then existed. Indeed, it is by some supposed that the atmosphere in those early times was so charged with carbonic acid that animals could not live in it: although it would be favorable to the development of vegetable nature. What astonishing changes has the surface, and the climate, and the vegetable covering of New England undergone! and how well adapted were they all to fit it for the residence of God's last and noblest work!

In general the theoretical views that have been presented in relation to the origin of the new red sandstone, will apply to the graywacke. One circumstance only, in relation to this latter rock, needs any additional remarks: and that is, the more decided evidence, which the graywacke presents, of the operation of chemical agencies in its production. This is obvious in the more crystaline aspect of the rock in general, and especially of certain varieties; and in the numerous veins traversing it, which must have resulted from a play of chemical affinities. And if it be admitted that internal heat in the earth, which every thing proves must once have been very powerful, has been gradually operating less and less upon the crust of the globe, why is it not a natural inference, that the older the rock the more crystaline would be its structure: that is, if we admit that the heat has been great enough to change the arrangement of the particles of rocks, whose origin was mechanical: and it appears that such a change may take place, to some extent at least, far below a melting heat. Only admit then, that the graywacke is an older rock than the new red sandstone, and we should expect in it a more chemical structure.

## 6. Metamorphic Slates.

I include under this term only those rocks whose structure has been decidedly changed by the action chiefly of heat, but which still retain traces of an original lamination or stratified structure. Where the parallel divisional planes have been obliterated, I shall treat of the rocks under the unstratified class. And where a change in the chemical constitution of the rock has resulted, I shall consider such metamorphosis under the particular rock which has experienced it.

So sure are geologists at the present day that most of the unstratified rocks have been in a molten state, that wherever they find stratified rocks in connection with them, they expect to find evidence, either of chemical action or mechanical disturbance. Indeed, some distinguished geologists carry their views so far on the subject, that they believe all the older stratified rocks are metamorphic: that they were originally sedimentary deposits, which have become crystaline by such an action of heat as would change their structure without obliterating the planes of deposition. Whether such a theory is tenable, is a matter of discussion: but that we have numerous examples of metamorphic agency, no geologist doubts. I shall now describe the most remarkable examples among the stratified rocks of Massachusetts.

### *Lithological Characters, Strike, Dip, and Localities.*

1. *Quartzose Aggregates.* I thus denominate a few varieties of metamorphic slate, because quartz is the predominant ingredient. The first one is a beautiful chocolate coloured slate occurring in small quantities in the midst of the metamorphic breccia at the head of Nantasket beach. It probably contains little else except quartz in a fine state, coloured by oxide of iron, or manganese, or both. (No. 1827.)

The most remarkable of these varieties is developed very distinctly at the southern extremity of Rhode Island; as may be seen by the sketch already given of that portion of the Island. It consists of coarse grains of hyaline quartz, of a purple color, passing to deep blue and black, with talc or mica; (it is difficult to say which;) the materials having a schistose arrangement. (Nos. 303 to 306.) The quartz bears a strong resemblance to peliom, and constitutes a large part of the rock. The aggregate exhales an argillaceous odor when breathed upon.

This same rock may be seen at the mouth of Fall River, in Troy, where it is associated with an argillaceous slate, passing into mica slate, and of a quite dark color from the carbonaceous matter it contains. At this place, this slate and quartz rock are contiguous to granite; and they may be seen in Tiverton, lying directly upon the granite. In Newport, also, granite cannot be far distant from the same rock. Do not these facts furnish a clue to the origin of the dark color of the quartz? Was it not penetrated by the carbonaceous matter of the black slate, while in a state of partial fusion by the action of the melted granite?

2. *Mica Slate.* In the south part of Bellingham, there occurs a remarkable metamorphic

rock. *It is a distinct mica slate, and a no less distinct conglomerate.* (Nos. 1853, 1854, 1855.) The mica has that glistening aspect which we witness in the oldest varieties of mica slate; and yet the rounded nodules of granite and quartz rock, sometimes several inches thick, are as distinct as in the newest conglomerate. A similar rock I found in bowlders at Wickford in Rhode Island, (No. 1861,) and it probably occurs there in place, as it does in Bellingham. At the latter place it passes into a fine grained variety of mica slate, such as is used for making whetstones, both there and in Smithfield, Rhode Island. The two rocks pass into each other, not perpendicularly but laterally; so that the same layer is partly made up of one kind and partly of the other; as may be seen in No. 1857. Hence I infer that all the whetstone slate of Bellingham and Smithfield is a metamorphic slate; (Nos. 2106, 2107, 2108,) and not improbably all the mica and talcose slates of Cumberland and Smithfield were produced in the same manner. In Bellingham this whetstone slate has a strike at the quarry, N. E. and S. W. and an easterly dip. In the N. E. part of the town, it runs N. a few degrees E. and dips E. 45°. In the south part of Bellingham, the mica slate runs N. W. and S. E. and dips at a moderate angle to the N. E.

Connected with the same mica slate conglomerate in Bellingham, there is a variety which I shall call *spangled mica slate*. A mineral, whose nature I do not feel satisfied about, is disseminated through a base of mica and quartz, so as to exhibit numerous shining points, when the specimen is turned over in the light. (No 1858.) In the extreme south part of Wrentham and Bellingham, and north part of Cumberland, is another variety of mica slate, which sometimes passes into chlorite slate, and sometimes into quartz rock. Often it contains somewhat rounded nodules of an epidotic substance, which I have often met in hornblende slate. (Nos. 1862, 1863.) The strata here run N. W. and S. E. and dip at a moderate angle to the N. E In the north part of Cumberland they are more nearly E. and W.

3. *Talcose Slate.* In the towns of Wrentham, Walpole, Canton, Randolph, &c., I have met with a chocolate colored slate, (sometimes light gray,) composed of quartz in fine grains, and slaty talc. (Nos. 320, 321, 322, 323, 1830.) I am not sure that in all these localities there is evidence of any very decided metamorphic action; and perhaps the specimens might with more propriety be placed under graywacke. In general, however, they lie very near to primary rocks. Connected with the metamorphic mica slate of Bellingham, we find a talcose slate which must be metamorphic. (Nos. 1859, 1860.)

I ought to remark that much of the mica slate of the narrow range extending from Monson to Warwick, resembles exceedingly the metamorphic mica and talcose slates which I have described. But I do not include them in this description, because I have not that decisive evidence that they are metamorphic from the agency of the adjoining primary rocks, which I possess in regard to the rocks in Bellingham and Smithfield.

4. *Argillaceous Slate.* The quarry of clay slate in Harvard, lies contiguous to a large protruding mass of granite, and the slate in general appears to be brought almost into the condition of mica slate But at the quarry I was surprised to find a part of it distinctly conglomeritic. (Nos. 1849, 1850, 1851, 1852.) This makes it almost certain that the whole clay slate deposit, extending from Worcester to the north line of the State, must have been originally a sedimentary deposit, and that it has been subsequently so altered by heat as to become highly glazed, and to lose its organic remains. But I have placed among the metamorphic slates only the altered conglomerates of that formation.

5. *Aggregates of Porphyry.* I have met with these in several places; and they are both conglomeritic and slaty. The best example of the former, perhaps, is in Hingham, a little west of the village; and in Cohasset, at the head of Nantasket Beach. At the latter place, is a coarse breccia, or conglomerate, which is chiefly made up of fragments of porphyry reunited by a cement of the same materials, and is sometimes almost reconverted into compact porphyry. The planes of stratification, although nearly obliterated, run E. and W., and the dip is N. This

rock might indeed be placed under graywacke; but the evidence of a powerful metamorphic action is so striking, that I thought the metamorphic slates a more appropriate place. A little west of the village of Hingham, is a conglomerate of analogous character, though usually of different ingredients and very obscure in its characters; being brought by metamorphic action into an intermediate state between several varieties of rock.

At the head of Nantasket Beach, is another metamorphic rock, lying contiguous to the breccia just mentioned, but which I find it difficult to describe. I incline to the opinion that it was originally a hard slate, like that on Nahant, and the Brewster Islands, which has been very much changed and filled up with veins of epidote, by the action of heat. Some of it appears as if converted into a sort of compact feldspar. The planes of stratification are apparently obliterated; but there are divisional planes visible, running E. and W. and dipping south. When the spray has wet the face of this rock, it shows a beautiful variety of colors, and even in hand specimens might be smoothed and polished so as to be employed for an ornamental stone. (Nos. 300, 1867, 1868.)

In South Natick, Needham, Plympton, Roxbury, Newbury, &c., we find a rock which is best described, perhaps, by calling it a slaty porphyry; generally, however, containing at least a glazing of talc. (Nos. 1823, 1832) It is evidently a recomposed rock, and probably resulted from the veins of porphyry and compact feldspar, which I consider essentially the same rock.

6. *Amphibolic Aggregate.* (No. 374.) Nothing is more difficult in many cases, than to determine the nature of the semi-crystaline minerals entering into the composition of some of the intermediate rocks. They seem to have undergone a chemical process, which has not been thorough enough to give them a fully developed character. In the present instance the mass appears decidedly crystaline; yet I am in serious doubt whether amphibole is the dark green mineral in it that exhibits a crystaline structure. Another part of the rock presents an argillaceous aspect and exhales an argillaceous odor when breathed upon. But had I found it among primary rocks, I should have regarded it as by no means an anomaly there: especially after finding in it a vein, four inches wide, of crystalized zoisite. The position of this rock, has already been pointed out, in describing the conglomerate of the southeast part of Rhode Island. The strike, if I have not mistaken it, is nearly N. and S. and the dip from 60° to 70° W.

7. *Varioloid Wacke.* The rock which I thus designate, has generally been regarded by those who have described the geology of Boston and its vicinity, as amygdaloid. But it seems to me that there are insuperable objections against the supposition that the nodules in general were introduced by infiltration, or even sublimation; the only modes by which geologists suppose the cavities of amygdaloid were filled. For they consist generally of rounded masses of compact feldspar; a substance which must certainly have been the result of igneous fusion. On the other hand, the rounded form of these nodules, and their non-crystaline structure in general, forbid the arrangement of this rock along with the porphyries. But some writers regard variolites as rather intermediate between porphyry and amygdaloid, (*Traite de Mineralogie, Par. T. S. Beudant, (Paris*, 1830,) *Vol.* 1. *p.* 569.) and such I suppose to be the character of the rock under consideration. By the term varioloid, I intend merely to designate the external aspect of the rock; since the mode of its formation seems involved in much obscurity: but its variolous appearance none can deny.

Brochant describes wacke as 'a substance intermediate between basalt and clay.' This description will apply to the base of the varioloid rock under consideration. It is found in Brookline, Cohasset, Natick, Newbury, Newton, Needham, Hingham, Brighton, and Saugus. But its most important varieties are found in the three latter places, and deserve a particular description.

In Brighton, the wacke is of a chocolate color, and quite hard. The nodules are mostly rounded, and of the size of a pea; but sometimes they are much larger and irregular, approaching to the form of veins. Compact feldspar, epidote, calcareous spar, and quartz are the princi-

pal minerals of which they are composed. Sometimes the external part of the nodule is compact feldspar, or calcareous spar, and the central part epidote: and sometimes quartz occupies the center, invested by epidote. The epidote is crystalized, although the cavities are in almost every instance entirely filled. The foliated structure of the feldspar, and especially of the calcareous spar, is not unfrequently visible, though generally these minerals are compact, and very hard. But the two last seem to be strangely blended, as if they had been partially melted together. (Nos. 373, 377.)

At a quarry about a mile southwest of Brighton meeting house, this varioloid rock may be seen passing into conglomerate, showing that it is only a metamorphic variety of the graywacke formation.

At Hingham, the greater part of this rock is of a deeper red than that at Brighton; though some of it is of a light gray. The basis is harder, owing perhaps to a mixture of compact feldspar. The nodules vary in size from that of a pea to that of an almond; and consist of brownish red and greenish compact feldspar, with carbonate of lime mixed with the latter, or in separate folia. Not unfrequently the red compact feldspar encloses the green, like that in Brighton. This rock is associated with a conglomerate of the graywacke formation. (No. 374, 1834.)

At the head of Nantasket Beach, I found a rolled mass (No. 375) of the varioloid rock, whose base is brownish gray, and the nodules a greenish compact feldspar.

In Needham, this rock has a somewhat slaty structure, is hard, and contains distinct crystals of feldspar of a light green color. (No. 378.) But as the basis is obviously wacke, exhaling an argillaceous odor, I can hardly persuade myself to place it among the porphyries. Suppose this Needham rock were to be subject to a degree of heat sufficient to fuse the feldspar, without essentially altering the wacke, I inquire whether the result would not be a rock very similar to some varieties that have been described as varioloid wacke. And may not this have been the mode in which some of that rock was produced?

The most remarkable of the varioloid rocks which I am describing, occurs at Saugus. Near the center of the place, and surrounded by granite, we find a rock, forming a hill one or two hundred feet high, composed of a basis of green wacke with imbedded nodules of white compact feldspar, with an occasional mixture of carbonate of lime. The nodules are rarely so large as a bullet; more commonly about the size of small peas, and in some parts of the rock so very numerous that it seems hardly possible they could have been infiltrated into cavities previously made. (No. 372.) The basis is a pleasant green. I saw no conglomerate or other variety of graywacke in the vicinity.

It is obvious from the preceding descriptions, that in some instances—particularly at Brighton—the nodules of this varioloid rock must have been at least partially formed by the infiltration of earths from a watery solution: but it would seem that this was only a part of the process. For it is difficult to conceive how such minerals as compact feldspar and carbonate of lime could have been deposited in a compact form from a watery solution; since they crystalize with so much readiness. It seems to me that we must call in the agency of heat, after the infiltration took place, by which the crystals might be converted into a compact mass, and all the cavities be filled, as they are in almost every instance: and if we suppose granite, sienite, &c. to have had an igneous origin, we can be at no loss to provide for the requisite heat. I had been rather disposed to regard much of this rock as an example of the solid concretionary structure, especially that at Saugus. But the occasional evidence of infiltration led me to abandon that hypothesis. If the one hinted at above is more satisfactory, I shall be gratified. The subject is certainly involved in much obscurity.

9. *Flinty Slate.* 10. *Chert.* 11. *Jasper.* I regard these rocks as varieties of other rocks, altered by the proximity of granite, porphyry, or trap: and in Massachusetts they are merely altered varieties of the graywacke formation. Hence I shall treat of them in this place. The

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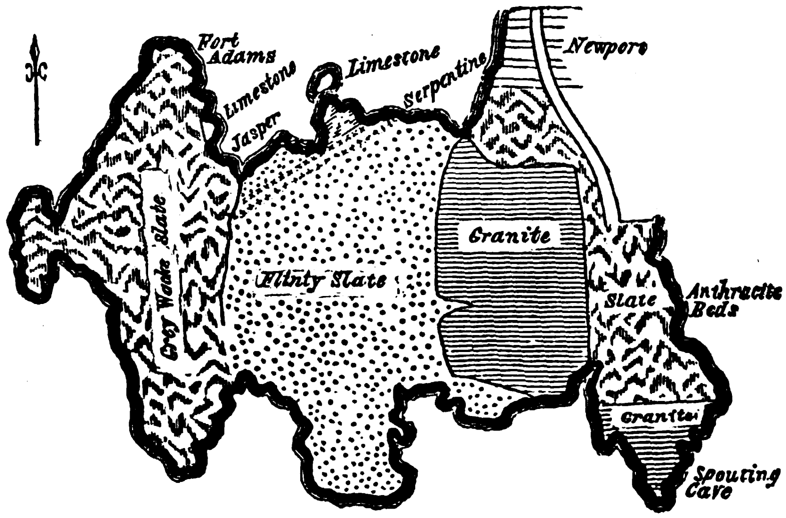
sagacious observations of Dr. Macculloch concerning the origin of these rocks, (*System of Geology*, *Vol.* 1. *Chapter* 40.) receive strong confirmation from their situation in New England. I shall exhibit the relative position of these rocks as intelligibly as possible, from the examinations of them which I have been able to make.

## *Flinty Slate, or Siliceous Schist.*

This rock I have found only in two places in the district which I am describing; viz. in Newport, R. I. and on the promontory of Nahant. It is interesting, however, that in the former place it occurs contiguous to granite, and in the latter, to trap.

It is not this slate alone which in Newport exhibits the influence of the proximity of granite: and it will save space to give an account here of the whole of this interesting spot, to which I was conducted by Col. Joseph G. Totten, who is at the head of the Topographical Bureau at Washington, and to whose polite attentions I am much indebted.

Fig. 109.




The preceding rough sketch of the southwest part of Newport, will give a correct idea of the relative position and extent of the four or five rocks which are there associated, on a surface of four or five square miles; viz. granite, flinty slate, graywacke slate, limestone, serpentine, and jasper. The flinty slate, it will be seen, occupies a considerable space immediately contiguous to the granite, and it is separated from the graywacke slate on its west side, by a small ravine. The flinty slate exhibits various degrees of induration, and more or less of a mixture of different minerals. One variety has a gray color, an imperfectly conchoidal somewhat splintery fracture, and is rendered porphyritic by small grains of hyaline quartz. Another dark gray variety exhibits greenish and white clouds. A third has a reddish base of an earthy aspect and fracture, less hard than the preceding, and contains numerous light colored, rounded masses, resembling hornstone, from the size of a pin's head to that of a musket bullet; giving it an amygdaloidal aspect. If hard enough to receive a polish, it would form an elegant ornamental stone. A third variety exhibits a semi-crystaline aspect, and contains minute scales of mica. This variety is traversed by veins of granite, composed of quartz and flesh-colored feldspar. (Nos. 380 to 383.)

For the most part, this rock exhibits scarcely no marks of stratification. But not unfrequently,

even in the most highly indurated masses, the traces of a former slaty structure are distinctly visible. In short, it is quite obvious, that it is the graywacke slate, which has been subject to a heat so powerful as to indurate, and for the most part to melt it. I think it would be easy to collect specimens exhibiting almost every gradation from graywacke slate to flinty slate.

In the southeastern part of the above sketch, the granite cuts off the graywacke slate at right angles to the general course of the layers; and the slate is indurated only a few feet from the junction. The junction between the granite and the siliceous slate is obvious in several places, particularly in a ledge at the southwest extremity of the granite: and the two rocks are so firmly united as to separate no easier than in any other direction.

The graywacke slate of this spot has generally the shining or glazed appearance of the oldest varieties of argillaceous slate: but in the extensive excavations that have been made in it for the construction of Fort Adams, we see frequent examples of a brecciated or conglomerated structure. It is also traversed by numerous small veins of white quartz, sometimes combined with flesh colored feldspar.

The serpentine is separated from the granite by a strip of flinty slate. At its eastern extremity it seems to lie between the flinty slate and the graywacke slate, and to have a stratified structure. But it probably extends to the southwest, (as shown on the sketch by the crosses,) so as to cut across the northwestern point of the siliceous slate. A valley passes through the flinty slate in the direction in which the serpentine runs, and at its extremity, serpentine appears in small masses attached to the flinty slate. It probably forms a vein in the slate, which is hid by the loose soil, though at its northeastern extremity the graywacke slate lies immediately north of it, as shown on the preceding sketch. The serpentine is compact, very hard, and of a very dark color. It might easily be mistaken for greenstone.

The limestone forms a small island, a little distance north of the serpentine; also a small point projecting into the harbor, near Fort Adams. It is nearly destitute of stratification, is perfectly compact, and nearly as hard as quartz. Its general color is a grayish white; but it abounds in gray spots, which resemble chert. (No. 495.) Indeed, the whole mass seems to be well advanced in the process of conversion into that substance. This seems to be the case referred to by Dr. Macculloch, when he says; "an attempt to the production of this rock (chert) is often observed where the process is still incomplete; and it is evinced by the extreme hardness which such limestones exhibit in the vicinity of granite." (*System of Geology, Vol.* 2. *p.* 285.) He refers here to the primary limestones, which are intermingled with siliceous and argillaceous matter: and that the limestone at Newport is primary, in the sense in which Dr. Macculloch uses the term, is evident from the fact, that near the serpentine, a portion of it is seen in the form of a bed, between the layers of graywacke slate: and the limestone associated with this rock, is precisely the kind that is apt to contain a considerable proportion of siliceous and argillaceous matter. In ordinary cases, limestone is rendered more crystaline by the proximity of granite: but where a certain proportion of argillaceous and siliceous matter is contained in it, the effect of heat will be to render it more hard and compact.

A portion of the graywacke slate near Fort Adams is converted into jasper. But a more particular description must be deferred till I have finished what I have to say concerning flinty slate and chert. I shall also have occasion to speak again of the striking evidence, which the group of rocks above described in Newport furnishes of the igneous origin of granite.

## *Flinty Slate of Nahant.*

The greater part of this promontory is sienite. But enough of the argillaceous slate remains at its southeastern extremity, to show the geologist the influence of trap veins in passing through it. These are quite numerous, both in the slate and in the sienite; and sometimes the green-

stone is intruded laterally between the strata of slate, in the form of beds. Yet the general dip and direction of the slate appear to be but little affected by these veins, although they frequently constitute more than half the rock. For the basset edges of the slate run nearly east and west, and dip northerly; which corresponds with the general direction and dip of the argillaceous slate in that region. Nearly all the slate, however, on this promontory is much indurated; and a considerable proportion of it converted into genuine flinty slate. The slaty structure is rarely lost, except at the junction of the greenstone and slate, where the two rocks are so intimately blended, that it is not easy to fix upon the spot where either of them commences. This corresponds with the opinion of Dr. Macculloch, that nothing but the requisite degree of heat is necessary to convert argillaceous slate into greenstone. (Nos. 383 to 385.)

## *Chert.*

In using this term I follow the definition of Dr. Macculloch, who represents it, if I understand him, (*System of Geology, Vol.* 2. *p.* 283,) as simply argillaceous limestone, or calcareous sandstone, that has been melted.

I have already described a conatus for the production of chert from the Newport limestone. But at Nahant the process seems in some cases to be nearly or quite completed. One observes there, that a considerable proportion of the flinty slate contains layers of a light gray substance, somewhat resembling in aspect and fracture, certain varieties of pottery. (No. 386.) On examination we find intermixed with this substance, a compact or even semi-crystaline limestone. In short, we observe every degree of induration and compactness from limestone to chert. There can be little doubt, it seems to me, that this is a genuine case of the conversion of argillaceous limestone into chert. For, says Dr. Macculloch, "originating in limestone, the transition from that rock into the chert, is often so gradual, that no precise point can be assigned where the term indurated limestone is no longer applicable." *(System of Geology, Vol.* 2. *p.* 284.*)* None of it, however, at this locality has that chalcedonic aspect which highly indurated chert often exhibits.

## *Jasper.*

The jasper at Newport, to which I have already referred, occurs a few rods south of Fort Adams. Two or three large blocks of graywacke slate lie upon the shore, a considerable part of which has been converted into red jasper, often mixed with a greenish, translucent, siliceous mineral, so as to from an imperfect heliotrope. Before the mouth blowpipe the greenish variety undergoes no change, except a loss of color: but the red variety loses its color, and becomes slightly glazed at the surface. (Nos. 387, 387 1-2.)

The manner in which this jasper has been produced, appeared to me quite obvious: indeed, if I mistake not, we see the various steps of the process. The rock contains a considerable quantity of the magnetic oxide of iron; which consists of one atom protoxide and two atoms of peroxide. Now the effect of heat would be to convert this moiety of the black protoxide into the red peroxide; and the iron would serve also as a flux for the fusion of the slate; and thus genuine jasper would be produced: for according to Mohs, "jasper, with its various kinds, is formed, if besides the oxide of iron, clay enters into the mixture, &c." *(Mohs' Mineralogy, Vol.* 2. *p.* 328. *Edinburgh,* 1825.*)* Those parts of the rock with which the iron did not mingle, would form hornstone or heliotrope; the latter deriving its green color from the slate, which has a greenish aspect. As the vicinity of this locality exhibits so many marks of the former action of powerful heat, can we doubt that in this manner the jasper was produced? and can we doubt but granite was the powerful igneous agent employed?

Saugus has long been known as a locality of fine jasper. It exhibits a blood red, and generally uniform color; though sometimes striped and clouded with white, so as to be very elegant when polished. (Nos. 388 to 390.) I have been surprised, however, to find how easily it may be fused by the common blowpipe, into a white semi-transparent enamel, containing bubbles; and I can have little doubt but it ought to be referred to compact feldspar, which conducts precisely in this manner before the blowpipe. I am inclined, however, to believe that it contains some argillaceous matter; and it must contain the red oxide of iron to give it its color. It occurs a few rods east of the hill of varioloid wacke, which has been already described, as composed of wacke and numerous nodules of compact feldspar and limestone. Now I suspect that the action of granite on this rock, has converted a part of it into this pseudo-jasper. For granite appears in place only a few feet distant from the jasper; though the actual junction is hidden. If this be the true theory, then the composition of the varioloid wacke is the same as that of the jasper; and since compact feldspar predominates in the former, it probably does in the latter. And if I mistake not, very much of the compact feldspar in the vicinity of Boston abounds in argillaceous matter, as well as iron. In Hingham, indeed, it greatly resembles the Saugus jasper, though of not so rich a color.

11. *Hornstone.* This term has been applied to so many substances, that it is necessary to say I mean by it "a mineral approaching near to flint, and differing from compact feldspar in being infusible;" which is the definition of Professor Leonhard. It differs from chert, which is usually regarded as a variety of hornstone, in being derived from a rock which contains no lime of consequence.

I have met with this rock in Massachusetts only in one spot; viz. in the north part of Weston: but I should not think strange if it should be found all along the line dividing the stratified primary from the unstratified rocks in the vicinity of Boston. In color and translucency it bears a striking resemblance to horn: yet the marks of the original lamination are exceedingly striking; the layers standing nearly perpendicular and running nearly N. E. and S. W. From this fact I infer that the original rock, out of which this metamorphic one has been produced, was a part of that system of strata exhibited on Plate 53, which runs nearly N. E. and S. W.: although it is now surrounded by unstratified rocks. This hornstone has the hardness of flint, a splintery fracture, and is infusible before the common blowpipe. Hence I conclude it to be highly sileceous.

This description applies to this rock in its most perfect, that is, its most completely fused condition. (Nos. 1871, 1872.) But it is sometimes softer, and appears to be passing into a slaty rock which may be graywacke slate. (No. 1870.) Not improbably varieties may be found that will afford good oil stones. I found this rock in the northeasterly part of Weston, on the turnpike from Waltham to Bolton.

Patches of metamorphic slates are marked upon the Geological Map, (Plate 52,) in Bellingham, Cumberland, and along the west side of Narraganset Bay: in Newport and Tiverton: in Fall River, Cohasset, Hingham, Saugus, Weston, and Newbury. In the latter place, on Kent's Island, a part of the rock appears to be the varioloid wacke, passing into trap; and some of it might even be regarded as trap. (Nos. 1818, 1819.) We have there, also, slates which appear to be more or less metamorphic. (Nos. 338, 347, 351.) I might add many other localities, where these metamorphic rocks occur in quantities too small to be noticed on the map: as in Duxbury, for instance, where we have some slaty rocks which I find it difficult to understand and name. (Nos. 1060, 1061, 1869.)

## *Mineral Contents.*

If we do not consider hornstone and jasper as simple minerals, and probably the strict principles of mineralogy will exclude them, the minerals found in these slates are few and unimpor-

tant. In Middleton, R. I. I have already described a vein, several inches wide, of crystalized zoisite. (No. 392.) Epidote, also, is not very uncommon; but it is rarely crystalized. Magnetic oxide of iron is frequently found in minute octahedra in some of the slates around Naraganset Bay. And I am inclined to believe that the deposits of iron and copper in Cumberland, R. I. ought to be regarded as belonging to these rocks; or rather, as lying at their junction with the unstratified rocks. But this point needs more careful examination.

### *Theoretical Considerations.*

It needs only a glance at the Geological Map to see that all the deposits of metamorphic rocks marked upon it, lie immediately contiguous to granite, sienite, porphyry, or greenstone. And in the present state of geology, this is a sufficient reason for the metamorphosis that they have experienced: because none now doubt but the unstratified rocks have been the result of fussion. I shall not in this place go into the inquiry, how far the facts that have been developed sustain the hypothesis, held by many distinguished men, that all the stratified primary rocks are metamorphic. For the arguments on that question will be better presented in the Fourth Part of my Report.

### 7. Argillaceous or Clay Slate.

This rock is evidently nothing but clay more or less indurated and divided into very thin layers. When only moderately indurated, the rock is called shale, and exists in that state in the coal formation. But when hardened so as to become somewhat shining in its appearance, it is called clay slate. When found in connection with graywacke, it sometimes contains organic remains, and has been called transition clay slate. But when these all disappear and the surface has much lustre, it is called primary clay slate, and is associated with the newest of the primary stratified rocks, of which it forms one of the members. These terms, however, are fast getting out of use; and probably the sooner they are gone the better.

All the clay slate in Massachusetts belongs to the oldest varieties; unless it be the narrow band which I have already described under graywacke, as occuring around Boston. This evidently occupies a lower place in the series than the graywacke; and fragments of it are sometimes seen in the conglomerates of the newer rocks: Hence I must regard it as an older formation than the graywacke. It is also entirely destitute of organic remains: as is all the clay slate in Massachusetts.

It is well known that in Europe, most of the clay slates exhibit laminæ of cleavage which do not coincide with those of original deposition. But I have sought in vain for such a distinction in the clay slate of Massachusetts. The rock has, indeed, very often a jointed structure, occasioned by oblique divis-

ional planes. And from the fact that the laminæ which form roofing slates in the deposits are often more even than those resulting from deposition, and that they frequently are inclined at a larger angle than the adjoining rocks, I am disposed to believe that they are usually laminæ of cleavage and not of deposition; that is, produced by chemical agencies subsequent to deposition. But probably in a majority of instances, I have found these laminæ abounding in minute undulations, and a slight difference of color was obvious in the different layers, which facts certainly lead to the supposition that they were produced by original deposition. Very probably, had I been able to spend more time in the examination of our clay slate deposits, and had they been more fully developed in the state, I might have discovered planes of stratification and deposition differing from those of cleavage. But at present I can only say, that when I speak of the strike and dip of the strata, I mean those divisional planes which form the slaty laminæ.

### *Lithological Characters.*

The common argillaceous slate, which, in its most perfect state, forms roofing slate, is the only variety of importance belonging to this formation. This passes by slow gradations into mica slate; so that it is often impossible to say where the one terminates and the other commences. Hence some of the specimens which I place under mica slate, other observers would place under argillaceous slate, and *vice versa*.

The laminæ in the best varieties are straight and even: but as the rock approximates to mica slate, they become minutely undulated, the surface resembling exceedingly that of certain shales of the new red sandstone already described. Some of these intermediate varieties are remarkably contorted: but these I shall describe under mica slate.

In Guilford, Vt. through which the Franklin County range of this slate extends, I have observed that it passes into a fine grained variety of chlorite slate, and even perhaps into novaculite. That range also abounds with tuberculous masses of white quartz. Veins of quartz also occur in it, as I shall have occasion to show more particularly; and in Guilford we find protruding masses of a porphyroid granite, passing into compact feldspar, and a slaty mixture of this last mineral and quartz. This granite cannot be distinguished in hand specimens from some of the trachytic rocks of Continental Europe.

### *Topography of the Clay Slate.*

With the exception of that in the vicinity of Boston, the Map exhibits but three ranges of argillaceous slate: viz. in the Counties of Worcester, Franklin, and Berkshire. And it happens that in all these cases, except perhaps the first, the principal part of the range lies out of the State, either in New Hampshire, Vermont, or New York. Two miles south of the center of Halifax, Plymouth County, also, I found a delicate variety of argillaceous slate, which I was informed was discovered in digging wells, and that it lay immediately upon granite. (No. 363.) But whether it exists to any considerable extent in that region I am unable to say.

### *Worcester County Clay Slate.*

Some geologists would probably regard the slate that forms the roof and floor of the mine of

anthracite in Worcester, as argillaceous slate; and maintain that the range of this slate in Worcester County, extends at least as far south as that spot. But I regard that slate rather as a fine mica slate, much impregnated with carbon, which gives it the appearance of argillaceous slate. In almost every case the scales of mica are quite distinct: and at a short distance from the mine, the rock assumes the characters of mica slate distinctly; though here, as in most of the range of mica slate extending from the mouth of Merrimack river to the State of Connecticut, much of the rock is so quartzose that it might perhaps be regarded as quartz rock. I have not found much well characterized argillaceous slate, south of Boylston. And north of this place, the country is so much covered with diluvium, and so little hilly, that the slate does not often come into view. I found the range, however, to become narrower on approaching the north line of the State. Its characters appear most fully developed in Lancaster, where it has been quarried for roofing slate; and here the range is broadest. How far it extends into New Hampshire I have not ascertained. In passing from Groton to Townsend, I saw frequent examples of protruding masses and veins of granite in this slate. It passes on either side into the peculiar mica slate, already spoken of in Worcester County: and in this latter rock protrusions of granite are not unfrequent.

### *Franklin County Clay Slate.*

It will be seen by the Map that this range occupies a considerable part of the town of Bernardston, passing into quartz rock on the east, and into mica slate on the west, and embracing a considerable part of two mountains of considerable height. It is not, however, till we pass into Vermont, that this slate assumes its most perfect characters. In Bernardston it is quarried, indeed: but not I believe for roofing. But in Guilford, which adjoins Massachusetts, several quarries are opened for this purpose. It there forms hills of considerable elevation; and such is its character farther north. It has been traced northward, in the valley of the Connecticut, 80 or 90 miles, in Vermont; nor do I know that its northern limit has yet been ascertained.

### *Berkshire County Clay Slate.*

This ought perhaps rather to be called the argillaceous slate of Rensselaer and Columbia Counties: for the principal part of it lies in New York, in the eastern part of these Counties. Near the western line of Massachusetts it passes into mica slate, talco-argillaceous slate, and chlorite slate, by taking mica, talc, and chlorite, more or less abundantly, into its composition. Some of the slate rock in Williamstown, New Ashford, Richmond, West Stockbridge, and Sheffield, approaches so near to clay slate that many geologists would thus regard it. But in all these places it seems to me to come nearer to mica slate than to clay slate: and I have represented the clay slate as entering Massachusetts only in Egremont; and there only a short distance. On Prof. Dewey's geological map of Berkshire, Columbia and Rensselaer Counties, in the 8th Volume of the American Journal of Science, he represents a range of clay slate extending along the western base of Taconic Mountain across the whole State, and it is succeeded on the west by a deposit of limestone. Extensive quarries are opened in the slate in Hoosac, New Lebanon, and Hillsdale. Throughout its whole extent, it dips at a high angle, apparently beneath the talco-micaceous slate of the Taconic Range.

### *Strike and Dip of the Strata.*

The following statements, compared with Plate 53, will give an idea of the strike and dip of this rock.

## *Worcester County Range.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Harvard at the quarry. | N. E. and S. W. | N. W. 30° to 45. |
| Lancaster. | N. several degrees E. | 45° to 90° W. |
| Shirley. | N. and S. | W. Small. |
| Pepperell and Townsend. | do. | 30° to 60° E. |
| Townsend Harbour. | N. W. and S. E. | S. W. Small. |
| Groton, west of centre. | N. E. and S. W. | S. E. |
| Bradford. | do. | 30° to 45° N. W. |

## *Franklin County Range.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Bernardston. | N. and S. | 20° to 90° E. |
| Guilford, Vt. | N. several degrees E. | E. nearly 90.° |

## *Eastern Part of New York.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Egremont. | N. and S. | 70° to 80° E. |

This is the usual strike and dip of this range except that the strike is usually several degrees E. of N. and W. of S. But this range scarcely enters Massachusetts.

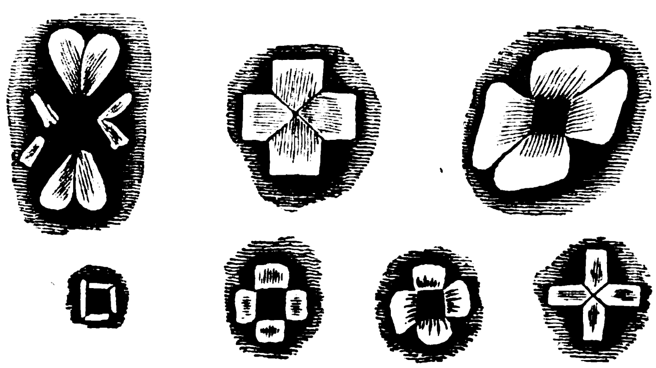
## *Mineral Contents.*

The slate west of the Taconic range sometimes contains octahedral crystals of magnetic oxide of iron, as well as the sulphuret of the same metal.

The clay slate in Charlestown, is frequently traversed by veins of crystalized quartz and calcareous spar.

The most interesting mineral in this rock is the chiastolite, or macle; which is found in Sterling and Lancaster. There is a great variety in the manner in which the prisms are disposed. The following are end views, of the natural size, of some of the most interesting forms.

Fig. 110.



This mineral is quite abundant in the clay slate in these towns, near the place where the rock passes into mica slate. It changes insensibly into the mineral which has been generally called andalusite; and which is doubtless the same species. I have found macle in small crystals in a loose mass of argillaceous slate in the town of Worcester. (No. 404.)

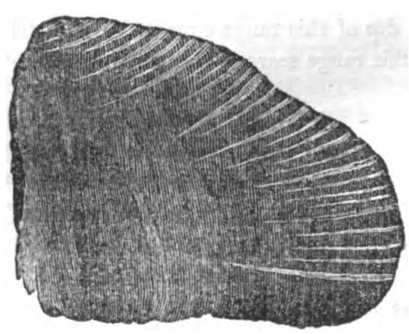
In the dark colored slate that lies immediately contiguous to the anthracite bed in Worcester, I found beautiful specimens of green amianthus, (No. 1549) and specimens, also, of bucholzite. (No. 1550): or, if it be not bucholzite, I am greatly mistaken.

## *Evidence of Disturbances in the Argillaceous Slate.*

I do not here refer to those agencies by which the strata of this rock have been elevated; nor to those by which its usual flexures have been produced; but to some movements that have taken place in certain anomalous directions. The instances which I shall refer to, all occur in the Franklin County range, and mostly in Guilford, Vt.

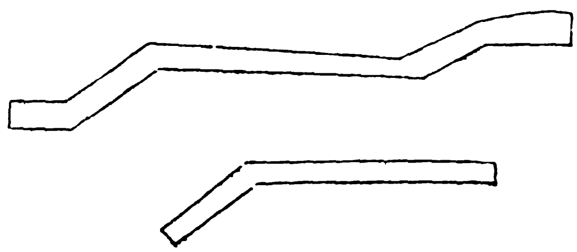
In some instances we find veins of quartz in the slate, as represented below. Here it is obvious, both from the curvatures in the undulating ridges of the slate, and from the wedge-form shape of the veins, that a force must have acted laterally on the edges of the laminæ, while they were in a partially plastic state; and that an infiltration of quartz must have taken place subsequently. It is not perhaps difficult to conceive how such a lateral action might have taken place, when the strata were originally elevated. The specimen from which the drawing was taken, (No. 411.) was found near the north line of Guilford, on the stage road.

Fig. 111.



In the principal quarry of slate in that town, on the stage road to Brattleborough from Greenfield, are seen occasionally divisional planes perpendicular to the horizon, and to the laminæ of the slate, which are nearly vertical, and run north and south. Not unfrequently, however, the slate at these cross fissures, when its edges are viewed from above, is bent as in the following figures, which exactly represent the specimens, No. 417 and 418.

Fig. 112.



In the latter case the flexure is so great that the slate is partially broken; and this is the case frequently; showing that when the disturbance took place, the rock was only imperfectly plastic. The quarry where these flexures are exhibited, has been so much excavated, as to leave a wall 20 or 30 feet high; and excepting at these transverse fissures, the laminæ are remarkably even: so that the phenomenon is rendered very striking. It must obviously have resulted from the unequal action of some disturbing force—perhaps that by which the strata were elevated—whereby one portion of the rock was pressed forward, faster than the rest; though in some places not enough to separate, but only to bend, the slate, while in a soft condition.

At the Gorge, or Glen, in Leyden, I found a series of such slides on a small scale, exhibited by the slate: as in the following sketch; though perhaps the rock ought to be regarded as mica slate. (No. 416.) Here the echellon movement took place in a direction at right angles to that described above.

Fig 113.

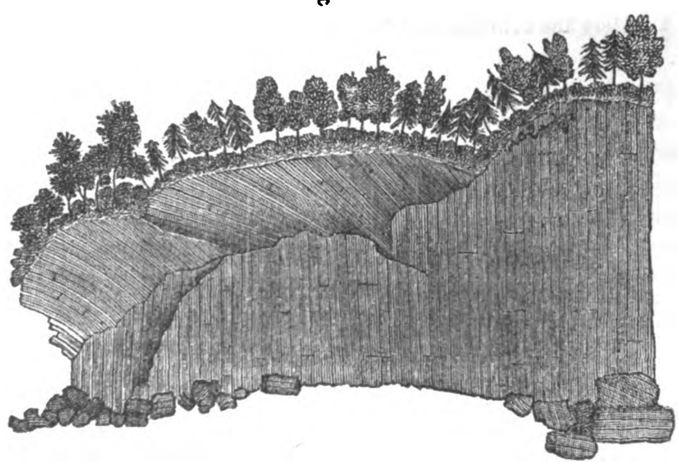
Another disturbance much more remarkable, appears at the quarry in Guilford above referred to. In the following sketch Fig. 114, the observer faces the north, and looks directly upon the edges of slate, as it remains at the north end of the quarry, in its natural position. The almost uniform dip of the laminæ, in every part of this quarry, is nearly 90°; leaning, however, a little to the east. And such is their position at the north end of the quarry, to the height of 15 feet, as represented in the sketch. But from 10 to 15 feet of the upper part of the slate are bent towards the west, so as to incline to the horizon at almost every angle, from 0 to 90°. Where the flexure commences, the laminæ of the slate are quite broken off, and not simply bent, as in the case of the disturbance in a perpendicular direction above described. Hence I infer that the former flexure was not produced so soon as the latter; not indeed until the rock had become perfectly consolidated. The quarry lies upon the western slope of a hill of slate, one or two hundred feet high; and the facts now related seem incapable of explanation, but by supposing a prodigious blow to have been given to the top of the hill, directed from east to west obliquely downwards. But what natural agent could have exerted such a force on such a point, I confess myself utterly at a loss to imagine. A similar case has been described in Middlefield, which might have been occasioned by diluvial action, but the direction of the force in the present case will not admit of such a solution.

## *Theoretical Considerations.*

When we consider the nature of the materials composing argillaceous slate, it seems difficult to assign any other origin to this rock, than deposition from water. Indeed, one has only to look at a clay bed, such as occurs in some of the tertiary and diluvial strata, which we are sure must have been deposited from water, to be satisfied that he has before him clay slate in its unfinished state; since nothing but the consolidation of the clay bed is want-

ing to convert it into perfect clay slate. But what agency could have effected this consolidation? Mere desiccation would do something, but we must call in the agency of powerful heat, and probably of galvanism too, to explain the elevation and dislocation of the strata, the production of various divisional planes, and the glazed appearance of the laminæ. Nor is there any difficulty in finding the requisite agency: for it meets us, in the form of trap, porphyry, and granite, in almost any district of much extent.

Fig. 114.



*Disturbance in the Argillaceous Slate: Guilford, Vt.*

## 8. Limestone.

No rock is more widely diffused in nature, or less liable to be mistaken, than the carbonate of lime. From alluvial marl to the saccharine limestones associated with gneiss and mica slate, we find an almost endless variety of this rock; but in nearly every case a drop of acid will enable a skillful observer to detect it and distinguish it from its associates. A more formidable difficulty has always met the geologist in assigning to the varieties of this rock their true places in the scale of strata.

Most of the limestone in Massachusetts belongs unquestionably to the oldest varieties of that rock. The newest varieties are the fetid and bituminous, which are associated with the new red sandstone, and which have been already described. I have also given an account of the white compact limestone of Attleborough and Newport, Rhode Island, and of the gray limestone of Walpole, which belong to the graywacke series. All the other varieties in the State, I shall describe in this place. And as the localities are rather numerous, and the diversities of composition, structure, and aspect, somewhat great; I shall, to save repetition, follow a topographical arrangement in the description.

### *Limestone of Bernardston.*

The most interesting fact respecting this small bed of limestone near the center of the town, is the occurrence in it of the remains of animals. The rock itself is highly crystaline, and so are the relics. They have an annulated appearance, like encrini: but the specimens are largest at

one extremity, and sometimes an inch in diameter; so that I doubt whether they are encrini. Perhaps they may have been chambered shells. But they are so nearly obliterated, that it is only where they are a good deal weathered, that we get much idea of their structure: so that I conceive the specimens to be too imperfect to exhibit upon a drawing: although I gave one in my former Report. They settle the question, however, that this is a fossiliferous rock. The strike of its strata is nearly N. E. and S. W. and the dip 20° S. E. The only strata lying above it are a variety of quartz rock; (No. 601,) which is not seen, however, in immediate contact. Nor on the other side do we see the clay slate beneath the limestone; although met with at no great distance. This, however, runs nearly N. and S. and the dip of the layers is very high. I doubt, therefore, whether this rock forms a bed in the slate. My present impression is, that it lies between the lowest strata of new red sandstone and clay slate. But this point needs farther examination; and it will probably be a difficult one to settle, on account of the coat of diluvium spread over the region.

Two species of iron ore occur in this limestone; the magnetic oxide, (*Aimant*, Beudant,) and the bog ore, or hydrate of iron, (*Limonite ocreuse*, Beudant.) The latter is disseminated through a large proportion of the upper layers of the limestone, and also forms masses, several inches thick, between these layers. It exactly resembles the common bog ore, so abundant in our alluvial formations. (No. 504.) This is not the only instance in which I have found this ore between the strata of other rocks, as I shall have occasion to show hereafter; and Beudant mentions several localities in Europe, where the *limonite* is found 'between the beds of divers rocks.'

The magnetic oxide occurs as a bed in the limestone, lower down than the bog ore. The bed follows the dip of the limestone, and that rock is much impregnated with the ore in the vicinity; so as sometimes to produce a sort of brecciated marble. (No. 472)

It is very obvious that both these species of iron ore must have been of contemporaneous production with the limestone, since it is impossible to conceive how parallel interstices could have existed between strata so little inclined, long enough to be filled by watery infiltration, or igneous sublimation, or galvanic agency. That the bog ore was deposited, as we find the same ore now forming, seems highly probable. But I am not aware of any theory which will satisfactorily explain how the magnetic oxide, which consists of 69 parts of peroxide and 31 of protoxide, could have been produced in conjunction with the limestone.

## *Limestone in Belchertown.*

This limestone occurs on the farm of Justus Forward, Esq., half a mile east of the meeting house. The specimen which was brought to me, and which I analysed, yielded only 25 per cent. of carbonate of lime. Its solution in nitric acid, also, was milky, indicating the presence of magnesia. But having visited the bed, I find much purer specimens. It occurs in gneiss, which there dips at a small angle to the northeast. The soil has so covered the limestone that the extent of the bed cannot be determined, until this is removed. The bowlders on the surface, however, indicate its extent to be considerable: and so valuable would be a good limestone quarry in that place, that I think some expense ought to be incurred by digging and blasting, to ascertain the nature and extent of this limestone.

## *Micaceous Limestone.*

This rock might very properly be regarded as a variety of mica slate: for usually it contains both mica and quartz, the latter always; and much of it is merely mica slate which takes carbonate of lime into its composition. When the carbonate is in small proportion, the schistose

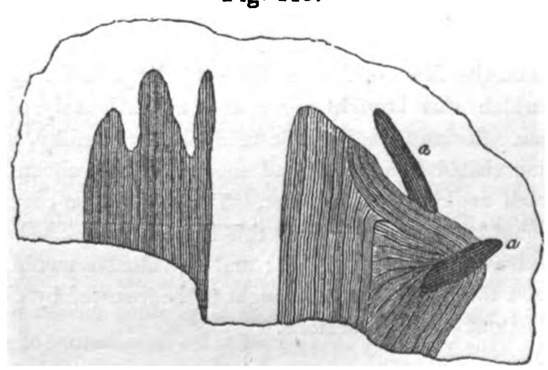
structure of the mica slate remains; but when the mica nearly disappears, the slaty structure also vanishes, though still the rock is stratified; the dip and direction conforming to those of the mica slate. It forms numerous beds in the extensive tract of mica slate on the western slope of the valley of the Connecticut; especially along the eastern border of the mica slate, from Whately northwards. Several beds are marked on the Map, merely to indicate that they are numerous, but without any intention of giving them their true situation and extent, except in Whately. In that place is the largest and purest bed that I have seen. (Nos. 459 to 467.)

From the analysis of two specimens of this limestone from Whately and two from Ashfield, on page 80, it appears that it contains but little magnesia, but a large mixture of siliceous matter.

The carbonate of lime in this rock is very liable to be separated from the mica and silex by the action of air and moisture, so as to leave the surface of the rock coated over with a gray porous mass, sometimes even several inches thick. (No. 467.)

This rock is frequently traversed by veins of granite. (No. 465.) The tortuosities of some of these veins is remarkable; of which examples will be given when I come to describe granite. I have not generally observed any very striking effects produced upon the limestone by its proximity to granite. In one case, however, if I mistake not, a large quantity of argentine has been produced by the action of the granite on the limestone. In a very wild and unfrequented spot in the northeast part of Westhampton, (not in the south part of Williamsburgh, as all the authorities state,) a huge mass of coarse granite lies in a valley, apparently in situ. At its southern extremity, which is represented on the following sketch, and which is an uneven perpendicular wall from 10 to 15 feet high, project the edges of schistose rocks; most of which is mica slate, but a part is micaceous limestone. These rocks appear to be merely the fragments which adhered to the granite, when it was raised through the slates, or when these were torn off from the granite. Most of the layers are perpendicular: but some of them towards the eastern side, are much bent and become almost horizontal. Here the argentine, *a*, *a*, appears, lying for the most part between the slate and the granite; penetrating both rocks, indeed, a short distance, but not forming what ought to be called a vein in either. It does not enter the granite, as far as I could ascertain, but a few inches. And it is that part of the stratified rock that lies in the vicinity of the argentine, which is micaceous limestone.

Fig. 115.




*Argentine with Mica Slate and Granite: Westhampton.*

Now my hypothesis is, that when the granite was protruded into the mica slate and coarse limestone, while in a melted state, its heat by decomposition or sublimation, or both, forced the carbonate of lime into the cavities that were produced by the elevation of the rocks, where it assumed the form of that very pure variety of carbonate of lime called *argentine* or *slate spar*.

Whether its intrusion among the sinuosites of mica slate caused it for the most part to assume a similar structure, I do not undertake to decide.

In Vermont, near Connecticut river, limestone is found among the layers of argillaceous slate. Here it is destitute of mica, and is mixed with the argillaceous slate in such proportion as scarcely to be distinguished from it, except by its effervescence with acids: yet it appears to be closely allied to micaceous limestone.

## *Limestone of Whitingham, Vt.*

This bed of limestone, as may be seen by the Map, approaches nearly or quite to the north line of Massachusetts, and lies near the junction of a range of talcose slate and gneiss. It is stratified and the dip is not far from 30° west, the direction being north and south. By following down a small tributary of Deerfield river, which has laid bare this limestone in the southwest part of Whitingham, a good opportunity is afforded for examining its characters. It is white and decidedly crystaline, though often containing bronze colored mica, and sulphuret of molybdenum in small plates. I found associated with it, also, actynolite, common augite, and mussite. Though a mile or two in length, the breadth of the bed is very inconsiderable. Its geological associations render it certain that it is one of the oldest varieties of limestone.

About 16 miles north of this bed, at an iron and gold mine in Somerset, is a very elegant variety of dolomite, occurring in beds in talcose slate. Some of it exceedingly resembles the purest loaf sugar. (Nos. 483, 484.)

## *Limestone in Bolton, Boxborough, Littleton, Acton, Carlisle, and Chelmsford.*

The geological situation of these limestone masses and their mineral character are so similar, that one description will embrace them all. They all correspond to the description which Dr. Macculloch gives of the limestone of Tirey, one of the Western Islands of Scotland. "It is," says he, "improperly called a bed, as it is only an irregular rock lying among the gneiss without stratification or continuity. In this respect it resembles the greater number of primary limestones found in gneiss and mica slate, and may be considered as a large nodule." (*Western Islands, Vol.* 1. *p*. 48.) It will be seen by the Map that all these masses are in a gneiss formation, which, however, often passes into mica slate, and contains numerous protrusions and veins of granite. The dip and direction of the gneiss surrounding the limestone are visible at nearly all the quarries: but the limestone itself rarely exhibits any distinct marks of stratification. And as every one of these localities contains a quarry, a good opportunity is presented for examining the structure of the rocks.

From the table of analysis given on page 80, it appears that nearly all the limestones from the localities under consideration, are highly magnesian; and some of them genuine dolomite. This fact will be referred to again in the sequel.

Nearly all the limestone at these quarries is coarsely granular and highly crystaline. It is almost uniformly fetid also; sometimes so much so as to produce nausea when struck, in a stomach of much sensibility. This was very unexpected to me in limestone of such great relative age.

Although but a single bed of limestone is marked upon the Map in each of the towns mentioned above, yet in most of them there are several; some of them one or two miles distant from one another. In Bolton are two, in Boxborough one, in Littleton three, in Acton one, in Carlisle two or three, and in Chelmsford two or three. Not improbably others exist in the neighboring towns, which escaped my notice.

The simple minerals imbedded in this limestone are numerous and interesting. In general,

specimens from the different localities cannot be distinguished; though particular minerals are more perfectly developed at some places than at others; and one or two, perhaps, are found only at one quarry. The most common and abundant mineral is scapolite. It occurs both crystalised and compact; and at all the localities above referred to. The crystalised variety is most abundant at Bolton, Boxborough, Chelmsford, and Littleton; particularly at the two first named places. The crystals are sometimes transparent, more commonly opaque and white, having begun to decompose. Sometimes the crystal exhibits the primary form, or a right square prism, acuminated by four planes set on the lateral planes. More commonly, however, the lateral edges are slightly truncated. Some of these crystals are one or even two inches in diameter; though in such cases generally imperfect. Often this mineral is compact, and the color either white or lilac red. This red color, however, occurs also in that which exhibits an aggregation of prisms. Bolton and Boxborough yield an abundance of this beautiful variety.

It is probable that the mineral from Bolton, described by Mr. Brooke, under the name of Nuttallite, is only a variety of scapolite.

Augite, actynolite, pargasite, and radiated, fibrous, and brown hornblende, are among the minerals found in this limestone; the two first at all the localities, the third at Carlisle and Boxborough; and the fourth, according to Mr. Nuttall, at Bolton.

Phosphate of lime, sometimes in hexahedral crystals, but more commonly massive, is found at Bolton, Boxborough, and Littleton; usually in scapolite. Its colors are green and purple.

Genuine petalite, (from which lithia has been obtained,) exists at the south quarry at Bolton, associated with the scapolite.

At Chelmsford small masses of black serpentine occur in the limestone, and at Littleton also, of a lively green color. They occur also at Bolton and form a good vert antique.

At Carlisle, close by the turnpike from Concord to Groton, Prof. Webster discovered a few years since, a splendid garnet, which is probably a cinnamon stone. The specimens which can now be obtained, give but a poor idea of the richness of some of those which were first procured. Probably extensive exploration might bring to light finer specimens. The same mineral is found at Boxborough.

At Bolton rhomb spar occurs: and both there and at Boxborough, a beautiful variety of flesh colored calcareous spar in foliated masses, often with disseminated crystals of pargasite.

At Bolton, also, a new mineral has been discovered, which Dr. Thompson has denominated from its chemical composition, ***Bisilicate of Magnesia;*** and Mr. Shepard, with reference to its locality, calls it *Boltonite.* (***Shepard's Mineralogy**, Vol. I. p.* 232.) It occurs in foliated masses in the limestone. (Nos. 521, 522.)

In the same place, at the south quarry, sphene, or silico-calcareous oxide of titanium, is not an uncommon mineral in distinct crystals. Tremolite, also, is said to occur there in fibrous masses: also gadolinite, according to Professor Webster: also talc in veins, as well as at Littleton.

Very delicate and beautiful amianthus is found in veins in the limestone, about two miles southwest of the center of Chelmsford. The fibres are sometimes two or three inches long, and resemble the finest and most beautiful white silk. The same mineral in small quantities is found at Bolton. (Nos. 523, 524.)

The spinelle of several colours has been found at Bolton, Littleton, and Acton. At Bolton and Littleton it is sometimes red, and forms a real Balass ruby. At the same places it is blue and hair brown; forming the pleonaste. The latter has also been found at Chelmsford, as well as Brucite, or chondrodite: and also a beautiful wine coloured garnet, like that at Carlisle, according to Dr. C. T. Jackson. The Allanite also occurs at Bolton. The spinelles usually occur in octahedra.

## *Limestone of Natick and Sherburne.*

In the Economical part of my Report, p. 89, I have given so particular an account of the situation of the limestone in these places and of the size of the beds in Natick, that nothing more need be added on these points. By the Table of Analyses on page 80, it may be seen that the rock from both these towns is highly magnesian, and in one instance a perfect double carbonate of lime and magnesia. The beds in Natick occur near the junction of the stratified and unstratified rocks; but I think within the limits of the gneiss formation. Here, however, it is only gneissoid; taking into composition a large proportion of hornblende, and passing into greenstone and sienite; and the whole mass is traversed by veins of trap, and has been exceedingly disturbed, so that it is only occasionally that we see distinct marks of stratification, or a laminar arrangement. A good opportunity is afforded at the rail road cut, where the bed of yellow compact limestone (Nos. 1949 to 1951,) is found, to observe all these varieties of rock, and their great irregularity and intermediate character.

## *Limestone in Smithfield, R. I.*

There are two principal beds of this rock, a little more than a mile apart; the most easterly one, half a mile from Blackstone river, called the Dexter rock, and the other, the Harris rock, occur in that variety of hornblende slate, which has been called transition or primitive greenstone. The slaty structure of a part of the rock is quite obvious, though to a cursory observer, most of the mass resembles very much secondary greenstone. Though the divisional planes of the hornblende be evident, yet the limestone is destitute of stratification; forming an irregular mass, penetrated by projections from the slate. It is white and distinctly, though not very coarsely granular and crystaline. Some of it is dolomite. (Nos. 498 to 500.) It may be, and has been, wrought as marble; though it is difficult to obtain large blocks without fissures. Sometimes it is clouded. (No. 497)

The imbedded minerals in this limestone, are, with few exceptions, very different from those just described in the limestone beds in gneiss in Massachusetts. In the Smithfield rock, talc is one of the most abundant of the minerals, and it is often of a rich silvery white color, associated with large prisms of rhomb and calcareous spar. Some of the nacrite found at the Dexter rock is beautiful. Nephrite exists here, also, in veins and nodules: also limpid quartz in crystals, calcareous and brown spar, tremolite and asbestus.

If, as seems to me extremely probable, the hornblende rock in which this limestone occurs, has been subjected to the action of powerful heat, we have a cause for the want of stratification in the latter. And the occurrence of immense quantities of sienitic granite in the vicinity, shows us whence the heat might have been derived.

## *Limestone of Stoneham and Newbury.*

In both these places the limestone is in irregular unstratified masses in sienite, except that the most northerly bed in Newbury is in greenstone: or rather, the rock appears often to be intermediate between hornblende slate, trap rock and sienite. For the most part, the limestone is either finely granular, or compact, and white. That at Stoneham is translucent on the edges; (No. 496.) and were it not for the numerous seams and cracks in it, would prove a very fine article for statuary and other ornamental purposes. Two or three quarries have been opened at each of these localities, only a few rods apart; but they are now abandoned.

Among the minerals at Newbury precious and common serpentine predominate: and these

being disseminated in the granular limestone, form the *ophicalce grenue* of Brongniart, (*Classification des Roches, p.* 96.) which he mentions as occurring at Newbury. (*Tableau des Terrains, &c. p.* 325.) Specimens of this variety may be seen among those that are polished in the collection; (Nos. 896 to 899,) although the geological position of this rock, if I have not mistaken it, is not above organic relics (*epizoique*) as that author supposes it commonly is.•

Another beautiful mineral, often running in veins through the *ophicalce grenue*, or the serpentine, varying in width from a mere line to half an inch, is green amianthus. When a specimen is newly fractured, this mineral presents a peculiarly rich appearance. Its color is grass green and yellowish green. (No. 872.) Common asbestus occurs in the same situation.

Fibrous limestone, or satin spar, occurs in the same connection. The fibres are sometimes four or five inches long, though the veins of this mineral are quite thin.

Tremolite in radiated masses is not uncommon in this limestone. Epidote also occurs here in crystals; and white and gray varieties of compact feldspar. Associated with the tremolite and epidote, is found massive garnet.

The limestone at Stoneham, is not so much mixed with other minerals as at Newbury. It occasionally, however, contains nephrite. This mineral melts with great facility before the oxy-hydrogen blowpipe, and without difficulty before the common blow pipe, into a yellowish slag or scoria. Another grayish green mineral occurs in nodules in the limestone, and might easily be mistaken for the siliceous infusible mineral that has been described by many writers under the name of hornstone. But it melts with ebullition, not only before the compound, but also the common blowpipe, into a shining black enamel. (No. 507.) It is probably the allochroite, mentioned by Prof. Webster in the Boston Journal of Philosophy, as occurring at Stoneham.

Limestone has rarely been found in other parts of the world, entirely embraced in unstratified rock. But I saw no rock in the vicinity of the quarries, except sienite and trap: although, as I shall have occasion hereafter to observe, sometimes the sienite north of Boston possesses a limited slaty structure, forming a kind of hornblende slate: the unmelted remnants, perhaps, of the rocks out of which the sienite was formed. That this rock had an igneous origin, seems to be at this day the opinion of geologists. And admitting this, it is easy to see why the beds of limestone, that have been described above, are destitute of stratification.

### *Limestone in Concord.*

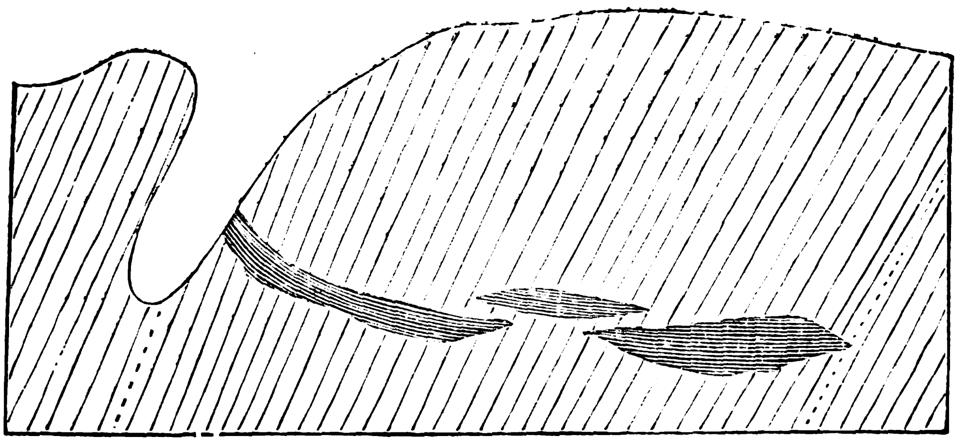
This is a limited bed in hornblendic gneiss, not far from the junction of the stratified and unstratified rocks. It differs from those already described from the same gneiss formation, in being of a darker colour and in not containing so much magnesia. I have analyzed, however, but one specimen.

### *Limestone in Middlefield, Becket, and Blanford.*

Near the eastern border of the gneiss deposit in the Hoosac mountain range, we find a few limited beds of limestone, whose characters are very similar, and not much unlike those of the beds in Bolton, Chelmsford, and other towns in that vicinity: that is, the stone is usually more or less crystaline, of a white colour, considerably impure, and highly magnesian. The bed in Blanford lies near the junction of mica slate and hornblende slate; which latter rock is very narrow, and is succeeded by gneiss; so that the limestone in fact, lies near this latter rock. The beds in Middlefield and Becket occur within the limits of the gneiss. It exists probably in the greatest quantity at the mouth of Cole's Brook. At that spot it is distinctly stratified, the strata dipping west at an angle of about 70° or 80°, corresponding with the strata of gneiss which lie upon the west side, and the strata of hornblende slate on the east side. The bed is almost four

rods thick; and an irregular granite vein, composed chiefly of feldspar, (No. 1983,) from one to four feet wide, crosses it nearly in a horizontal direction; as is shown on Fig. 116. This has produced no mechanical disturbance in the limestone; nor, as I could discover, any chemical effect, except perhaps a degree of induration. This is the only example of a vein of unstratified rocks in white limestone that I have met of any importance; although at one of the quarries in Bolton, a large mass of granite shows itself in such a position as to render it probable that it is a vein. The width of the bed is shown by the dotted lines.

Fig. 116.



The bed of limestone at Cole's Brook extends southerly into Becket, across the west branch of Westfield river; and there it is crossed by the Western Rail Road, which cuts through it to a considerable depth. The bed is there 54 feet thick; and on its east side is hornblende slate, as in Middlefield; while on the other side we find a graphic granite, much resembling the vein already described at Cole's Brook. And I have been led to inquire whether that vein, as well as the mass of graphic granite bounding the limestone in Becket, may not have been produced by segregation rather than injection. A few rods further east, the Rail Road crosses a second bed of limestone, whose exact thickness I could not ascertain. About a mile farther east, it crosses another large bed in Middlefield; that is, on the north side of the river. In all the beds on this river, a delicate variety of serpentine is mixed with the limestone; or rather it seems as if a part of the limestone itself were changed into serpentine, and the rock becomes a delicate verd antique. In the south part of Becket the limestone shows itself in two places, and is probably a continuation of the bed at Cole's Brook. In no place, however, is it so distinctly stratified as at that brook; though the lithological characters are similar, as well as its chemical constitution, at all the beds. Except the serpentine just mentioned, no simple mineral of importance occurs in any of these beds. I noticed, however, at the bed in the southeast part of Becket, poor specimens of tremolite, and an aggregate of limestone, talc, and sphene.

## *Limestones of Berkshire.*

The limestone which I have thus far described, exists only in quite limited beds. But as we pass westerly into Berkshire County, we find extensive ranges of this rock, interstratified with the slates which there abound. They form a portion of one of the most extensive deposits of limestone in the world; extending almost uninterruptedly from Canada, along the western part of Vermont, Massachusetts, and Connecticut, and the eastern part of New York, into New Jersey, Pennsylvania, and Virginia; and probably much farther; and being many miles broad.

## Lithological Characters.

The predominant characters of the Berkshire limestone are a white colour and crystaline structure. But other varieties are common; and perhaps I shall do best to describe them in order.

1. *Simple Carbonate of Lime.* This is sometimes exceedingly fine and beautifully crystaline; as may be seen at North Adams, Lanesborough, New Ashford, West Stockbridge, Egremont, and Sheffield. (Nos. 1899 to 1909. *See also the Table of Analyses, p.* 80.) The purest varieties are white; but the colours change to grey and even almost to black. (Nos. 1912 to 1917.) The rock also becomes often finely granular and compact. As a general fact, the limestones that are a pure carbonate of lime, or but slightly mixed with magnesia, occupy the western part of the county; though these are sometimes interstratified with the next variety.

2. *Magnesian Limestone, or Dolomite.* This is either a double carbonate of lime and magnesia, or a carbonate of lime mixed with a large proportion of the double carbonate: for where magnesia exists in limestone, I cannot doubt but it forms a double carbonate; and that the excess of simple carbonate of lime is mixed with it. We find magnesia in these limestones in almost every proportion; as a reference to the Table of Analyses on page 80, will show. We find, also, perfect examples of the double carbonate, or dolomite. All these varieties may be seen in Nos. 1924 to 1938, and in many other specimens in the State Collection. The dolomite is frequently highly crystaline, often finely granular, and sometimes pulverulent, but rarely compact. The dolomite decidedly predominates along the eastern border of the limestone range, though sometimes interstratified with the pure carbonate of lime. But where the rock is all dolomite, it can hardly be said that the rock is stratified at all, as in Dalton and Lee; where this variety is more fully developed than any where else in the county. This want of stratification is a very distinct character in the dolomites of Europe; especially in the Alps; and to give some idea how nearly some in Berkshire correspond in this respect to those in Europe, I have given, on Plate 55, a rough sketch (O) of a hummock of dolomite in Lee, directly across the road from the residence of the late Rev. Dr. Hyde. Its resemblance to a mass of granite is very striking. The length of the base of this hummock is 5 rods.

The crumbling down of the dolomite so as to form a white sand, is often a striking character. I have noticed it in New Marlborough, Sheffield, and Lee. But it is exhibited more strikingly in the town of Canaan, lying south of Sheffield, in Connecticut: it results probably from a law of chemical combination, that the more numerous the ingredients in a compound, the more feebly are they held together.

Both the simple and the magnesian carbonate of lime in Berkshire are frequently fetid, so as to give a strong odor when struck with a hammer. The same is true of the crystaline dolomite of Bolton, Chelmsford, &c. which occurs in the midst of gneiss. This odour, therefore, cannot give us any clue to the age of the rock, or prove that it has not been subjected to powerful heat: for the limestones in the eastern part of Massachusetts must certainly be regarded as among the oldest on the globe; since they lie between almost perpendicular strata of gneiss; and there is decisive evidence that they have been subjected to strong heat. Indeed, I might mention that I have frequently found fetid quartz an ingredient of the coarsest granite. It seems difficult, however, to explain this peculiar odour without supposing it to have an animal origin.

An interesting property in the dolomitic limestone of Berkshire, is its flexibility. I do not know that it is always flexible: but I suspect this property to be more common than is generally supposed. The best locality with which I am acquainted, is in New Ashford; where slabs of it have been got out that would bend almost like a lath, when properly wet. No. 501 is a sample; though not so good as has been found. This contains only 16 per cent. of magnesia: and yet I can hardly doubt but this is the cause of its flexibility, by weakening the force of at-

traction between the particles, and giving that finely granular texture that seems almost peculiar to dolomitic limestones. No. 1932 is a slab of the beautifully clouded marble of Great Barrington, and it is considerably flexible. This has such a texture as has just been described, and contains 38 per cent. of magnesia: so that it is almost a pure dolomite.

2. *Micaceous Limestone.* This usually occurs only at the junction of the limestone and mica slate, nor is it very abundant. The most remarkable variety that I have met, occurs in the southwest part of Cheshire, on the road to Lanesborough. The resemblance of this rock to gneiss is so great, (No. 1960,) that it was only because I knew of no gneiss in that region, that I was led to examine it. I did not find it in place; but it is probably connected with the mica slate of Saddle mountain. Other examples of micaceous limestone may be seen in Nos. 1966, 1967, and 1962. The two first Nos. are examples of a rock pretty widely disseminated in the County, showing itself particularly in the east part of Saddle mountain, and on the road from South Lee to Stockbridge. I have referred to this rock in the first part of my Report, as producing a salutary effect upon agriculture by decomposition.

3. *Talcose Limestone.* I have noticed this variety but very rarely and in small quantities; only in Williamstown and Becket. Nos. 1964 and 1966, will furnish examples.

4. *Quartzose Limestone.* A rock occurs near the principal village in West Stockbridge, which appears exceedingly like stratified quartz rock; and in fact it appears to be made up of granular quartz and carbonate of lime with a few scales of mica. (No. 1969.) Micaceous limestone occurs in connection with it. (No. 1968.)

5. *Augitic Limestone.* This consists of granular dolomite and crystaline disseminated masses of green augite. I have found it chiefly in New Marlborough. White augite sometimes occurs in the same rock: as in Tyringham, (No. 1974,) Sheffield, and Canaan, Ct.

6. *Feldspathic Limestone.* I have seen this only at the lime quarry in the south part of Tyringham. The rock is dolomite with disseminated masses of foliated feldspar. (No. 1970.)

7. *Granitic Limstone.* This is composed of quartz, mica, a little feldspar, and limestone. It very much resembles dark colored granite; or rather granitic gneiss; although I have seen in it few marks of stratification. I have met with it nowhere but in South Lee; and I apprehend that it forms a part of Beartown mountains, that lie immediately south of that place, and with whose geological structure I do not feel myself as much acquainted as I ought to be. (No. 1971.)

8. *Bi-silicate of Lime and Trisilicate of Alumina.* (*The Scapolite Rock of my former Reports.*) Although this singular compound does not perhaps extend into Massachusetts, yet being close upon our limits, in Canaan, Ct. and having been described by me in former Reports, before any geological survey of Connecticut had been ordered, I shall notice it again; especially as I have some new facts to state respecting its chemical constitution. From its behaviour before the blow pipe, I was led to refer it to scapolite. Afterwards I re-examined it, at the suggestion of Prof. Shepard, and thought it might be nephrite, or saussurite. This was his opinion: but he afterwards referred it to pyroxene. (*See Geological Report, p.* 135.) Wishing if possible to remove this uncertainty as to its nature, I requested Dr. Samuel L. Dana, to undertake its analysis; and he very obligingly complied with my request. The results I shall give in his own words, in a letter dated Dec. 20th, 1837.

"The results of two analyses gave,

| | |
|---|---|
| Silica, | 53 366 |
| Protoxide of Iron, | 4.499 |
| Alumina, | 10 380 |
| Lime, | 25.804 |
| Magnesia, | 1.624 |
| Carbonic Acid, | 4.000 |
| Loss. | 0.327 |
| | 100. |

"Deducting the equivalent of lime for the carbonic acid, we get 5.090 lime=9.090 carbonate of lime; and have 20.714 lime for the silica. If now we throw out the carbonate of lime and magnesia as belonging to the dolomite, in which the "Scapolite" occurs, and consider the lime as a bisilicate, and the alumina as a trisilicate, we have then,

| | | | |
|---|---|---|---|
| Lime, | 20.714—\|—Silica 23.672 | =44.386 | Bisilicate of Lime. |
| Alumina, | 10.380—\|—Silica 27.678 | =38.058 | Trisilicate of Alumina. |
| Oxide of Iron, | 4.499—\|—Silica 1.999 | = 6.498 | Silicate of Iron. |
| | Silica, 53.349 | | |

"The silica is thus less than the quantity found by 0.017. This composition agrees with no known mineral. The "Rock," therefore, which you have called "Scapolite Rock," must be considered a new species; consisting essentially of bisilicate of lime with trisilicate of alumina."

In a letter dated Nov. 2d, 1840, Dr. Dana adds the following.

"Jameson's Edinburgh Journal, has recently come to hand—the No. for October. I have just cast my eye on the following, which, as you see, is a variety of your "Scapolite Rock:" containing about three times its alumina. It is a bisilicate of lime, with silicate of alumina; while your Scapolite contains bisilicate of lime and trisilicate of alumina. Yours seems a mixture of Table Spar and Lenzinite; while this new mineral is a mixture of Table Spar and Bucholzite. I thought you might like to see the account, and here it follows from my notes."

"*Barsowite:* Colour snow white, massive and feebly pearly, compact, dull: fracture splintery or imperfect foliated. Translucent on edges. Hardness between apatite and feldspar. Sp. gr. 2.740 to 2.752. Before blow pipe melts with difficulty, and only on edges; with borax, slow and calm, into a transparent glass. In powder, heated with muriatic acid, forms thick jelly."

| | | |
|---|---|---|
| Composition: | Lime, | 18.16 |
| | Alumina, | 32.76 |
| | Silica, | 49.08 |

"Found only in loose blocks, sometimes of several cubic feet size, in the gold sand of Barsowskoj in the Urals. Blue crystals of corundum, black grains of Zeilanite, and white folia of mica, occur in it. It much resembles scapolite, distinguished by structure, relation to blowpipe and acid."

From the preceeding statements it appears, first, that *if* the Barsowite be a new mineral, so is the scapolite rock of Canaan: Secondly, that on strictly chemical principles the latter must be regarded as specifically distinct from the former, since it contains two proportionals of alumina more. And finally, if it should be regarded as a distinct species, the right to bestow a name upon it would certainly belong to Dr. Dana, who so long ago determined its nature. I shall not do this, both for the reason just mentioned, and because I am not sure that minerology has yet attained that perfect state which enables it to separate, without confusion, substances so nearly allied. But I feel safe in assuming that this compound constitutes a new rock. For in Canaan it occurs in mountain masses. Its strata, which I have traced 6 or 8 miles, with a width from 100 to 150 rods, runs nearly N. W. and S. E. and dip usually as much as 45° N. E. I think that this rock is underlaid by the dolomitic limestone and overlaid by mica slate; though I did not see the actual junction with the latter rock. Where it passed into the dolomite, there is a gradual mixture of the two rocks. In the present variety the planes of stratification are remarkably regular. Sometimes it is mixed with dolomite, quartz, and mica. (Nos. 540 to 544.)

## *Strike and Dip.*

**In all other parts of the State except Berkshire, the beds of limestone have the same strike and dip**

as the rocks containing them. In Berkshire, also, they correspond to the rocks with which they are interstratified; that is, the strike is N. a few degrees E. and S. a few degrees W. and the dip easterly. Yet it will be seen from the following statements that there is a good deal of irregularity in both these respects.

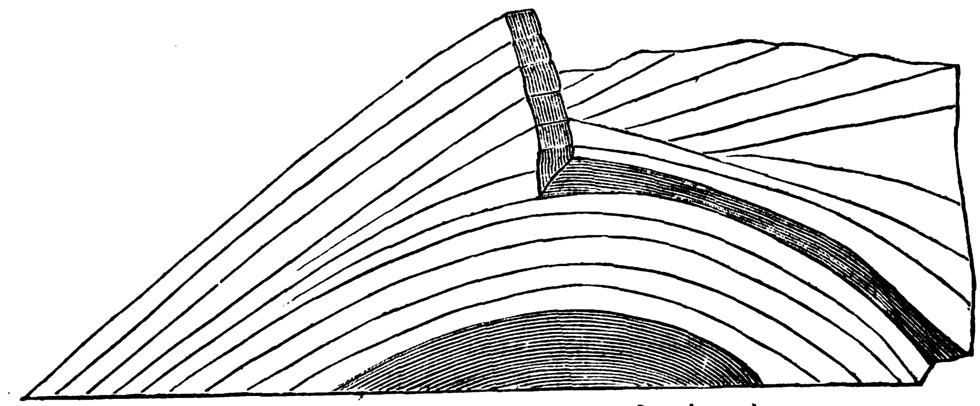
| | *Strike.* | *Dip.* |
|---|---|---|
| Sheffield, Girard College Quarry, | N. and S. | 60° to 70° E. |
| New Marlborough, West Part, | do. nearly. | E. irregular. |
| Boston Corner, | A little E. of N. | 50° to 60° E. |
| Egremont to Great Barrington, | N. and S. nearly. | E. large. |
| South Egremont, | N. E. and S. W. | 90° nearly |
| G. Barrington, Valley E. of South Mt. | N. and S. | 20° W. |
| Beartown Mt. South Side, | N. W. and S. E. | N. E. small. |
| Monument Mt. to Alford, | N. and S. | E. small, sometimes 90°. |
| Richmond, S. part, | do. | 30° E. |
| Lenox, E. part, | N. W. and S. E. | S. W. |
| Tyringham, near Shaker Village, | E. and W. | S. 20.° |
| Lee, N. part, | N. and S. | E. 45.° |
| Washington, W. part, | do. | E. large. |
| Dalton, Center, | N. W. and S. E. | 30° to 45° S. W. |
| New Ashford, Kent's Quarry, | N. and S. | 30° E. |
| Williamstown, N. W. base of Saddle Mt. | N. E. and S. W. | 45° S. E. |
| do. W. Side of do. | N. and S. | E. moderate. |
| do. W. outlet of Hopper, | do. | do. |
| N. Adams, Hudson Brook, | do. | E. 25.° |

## *Convolutions and disturbances of the Strata.*

In several cases I have noticed remarkable convolutions of the limestone strata, which it is not easy to describe or explain. Professor Dewey has given a striking example of one of these in Williamstown, with a drawing, in the 9th volume of the American Journal of Sience. In that case the strata appear to be so doubled upon one another as to form a very acute angle. But in the cases which I have noticed, we have them arranged in curves, with a radius often of several rods in length. In short, every appearance which I have witnessed, may be explained by supposing the strata to form huge concretions, having the shape of a paraboloid or ellipsoid, Different sections, of such a figure will of course present curves of different shapes. Fig. 117 is a sketch of the south end of Baker's quarry in Lanesborough, 4 rods wide. The curvatures here might be explained by a simple flexure upwards, in consequence of an elevating force, exerted either laterally or beneath. But it may, also, be regarded as a portion of a paraboloid.

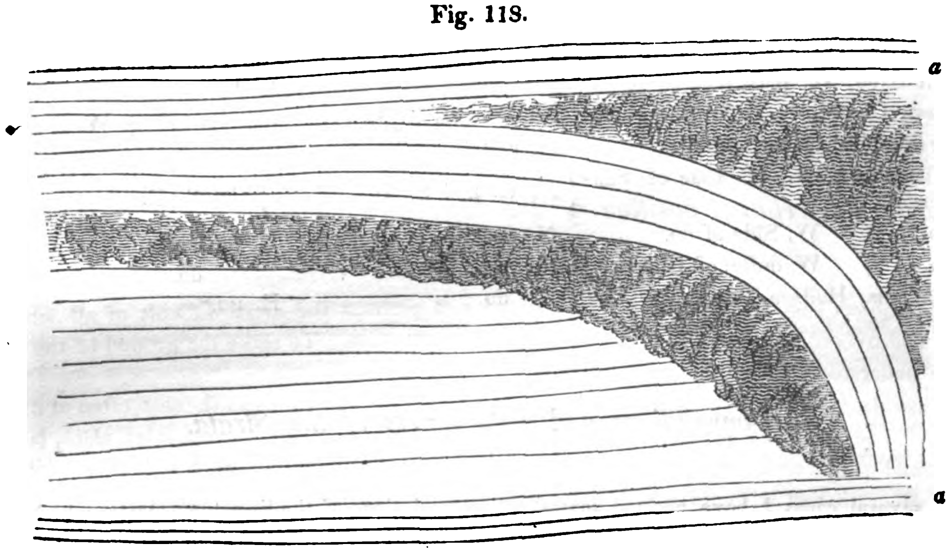
Fig. 118, is a sketch of a spot, 15 rods long, near the center of New Ashford, embracing Col. Kent's lime quarry. *a*, *a*, represeut the strata of mica slate on each side of the bed of limestone, dipping east about 30°. Although the intervening limestone is considerably hidden by the soil, yet a curvature on a large scale may be seen, as represented upon the sketch; which however, conveys a very imperfect idea of the spot.

Fig. 117.



*South End of Baker's Limestone quarry: Lanesborough.*

Fig. 118.

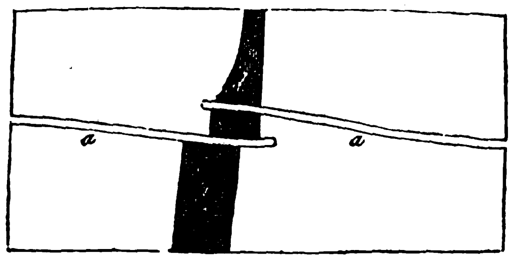


*Curvature in Limestone Strata: New Ashford.*

At one of the largest quarries in West Stockbridge, called the *old quarry,* this curved structure is very manifest; and there is an appearance as if an enormous concretion existed there. Indeed, it is my present belief, that these curved strata ought to be regarded as a variety of concretion, produced by heat, in the same manner as analogous concretions are formed in the unstratified rocks. I think, therefore, that probably the parallel divisions of the Berkshire limestone are not always the true original planes of stratification, produced by deposition. This may account for many anomalies in the strike and dip of the strata, as given on the last page.

The manner in which the veins of calcareous spar and the folia of slate are interlaced in this limestone, is often very complicated and difficult to explain. I will give only a single example in Fig. 119, sketched from a slab of nearly white marble, taken from a quarry in New Ashford. The slab is 5 feet long and 3 feet wide.

Fig. 119.




*a, a*, is the vein of calcareous spar, and *d, d*, a somewhat wedge shaped mass of dark gray limestone, five inches wide at its base, which is twice cut off, once by each separate portion of the vein. At present there are no fissures at all in the slab, and apparently it would not break more easily in one direction than in another. As to the strip of darker limestone, *d, d*, there is no more difficulty in accounting for its presence, than for any other close union between different varieties of a rock. But if we suppose the two veins, *a, a*, to have been once united endwise, it is extremely difficult to imagine how they could have been so slidden as to be brought into their present condition. Dr. Macculloch has described a similar case of disturbances in a slab of marble from Ireland in the Transactions of the Geological Society. (*Vol. IV. p.* 393.) But in that case it was not difficult to imagine how the fragments of the vein, by a series of slides, might have been displaced in the manner exhibited upon his drawing. In the present case, however, I despair of being able to explain that sort of double *echellon* movement, by which both the vein and the dark mass of limestone have been displaced.

## *Age and relative position of the Berkshire Limestone and associated Rocks.*

The subject suggested by this caption, has proved perhaps the most difficult of all which I have endeavored to explain in the geology of Massachusetts. To make the ground of the difficulty understood, some facts must be stated.

It has already been stated that this limestone, as a general fact, dips to the east, often at a large angle. The same is true of all the other rocks in the county, viz. gneiss, mica slate, talcose slate, and quartz rock. With all these the limestone is interstratified. In New Marlborough and Tyringham, it will be found in beds between the strata of gneiss; as at Hadsell's lime quarry. Its interstratification with mica slate may be seen in numerous places in all parts of the county. Yet it is a curious fact, that I have never met with the talcose slate in direct contact with the limestone: although sometimes separated from it only by a few feet of mica slate, having the same dip and direction: and therefore the talcose slate may be regarded as interstratified with the limestone. At some of the limestone quarries in W. Stockbridge, the mica slate and the limestone may be seen in direct contact. A sketch of this is given at Section L, on Plate 55. It shows the south wall of Boynton's quarry, in West Stockbridge, with the mica slate on the east or upper side. Section H, on the same Plate, extends westerly from the west side of the *Old quarry*, near the middle of the same town, across a hill of talcose slate of considerable height; thence across a valley to the top of the Taconic Range. The interstratification of the three rocks is here manifest, although the actual junction is sometimes hidden by a short space of soil. At the west base of the Taconic mountain, at Boston Corner, the limestone is seen passing under the slate; although here the actual junction is concealed by the soil. I do not recollect ever to have met with a spot where the

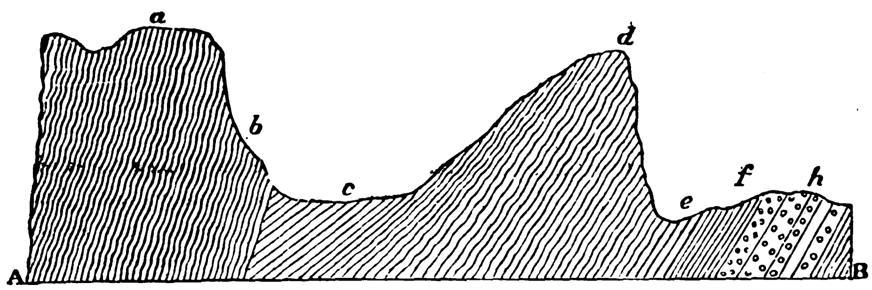
limestone is in direct contact with quartz rock. But as this rock frequently alternates with gneiss and mica slate, and the latter with the limestone, they must all be regarded as interstratified with one another. If we pass a little beyond the west line of Massachusetts, we find the limestone alternating with argillaceous slate: though perhaps the limestone there ought to be regarded as of a different age from that connected with the older rocks, above mentioned.

From the preceding facts, I think we may certainly infer that the limestone of Berkshire county is of the same age as the rocks with which it is interstratified; and since these are of somewhat different ages, though mostly primary, so is the limestone. The great difficulty in the way of this conclusion, however, has not yet been stated.

By consulting the Geological Map, Plate 52, in connection with the Sections A and B, on Plate 54, across the northern and central parts of the State; and Section E. on Plate 55, across the southern part of the State, it will be seen, that if we pass westward from Connecticut river until we strike the primary strata, we shall find them dipping easterly at a large angle: except towards the south part of the State, where they dip westerly at a large angle. As we advance towards the summit of Hoosac mountain, they become perpendicular, and continue so nearly to its western declivity. As we descend into the valleys of Berkshire, we find considerable irregularity in the dip; but in general, it is easterly, and the angle large. In the valleys, however, it is rather smaller than we find it upon the Taconic Range, that bounds those valleys on the west, and which is composed mostly of talcose slate. The easterly dip on this ridge is usually very large, not unfrequently 90°. Along its western base, we find clay slate with a similar dip, though not as great. As we go towards Hudson river from this slate, we first meet with limestone, evidently of a newer date than that east of the Taconic range: Then succeeds graywacke and graywacke slate; and finally, clay slate to the river. All these rocks have a large easterly dip: which, however, does not extend, as I understand, much beyond the river until we go as far south as the Highlands.

Now it is most obvious, that as we pass from the top of Hoosac Mountain towards Hudson river, we are continually meeting newer and newer rocks. To the gneiss of Hoosac Mountain succeeds quartz rock; then limestone and mica slate interstratified; then talcose slate; then clay slate; then a dark nearly compact limestone; then a distinct fragmentary rock with beds of slate; and finally clay slate. The two latter at least contain organic remains. And yet, over the whole distance, the newer rocks appear to pass under the older. Fig. 120 will perhaps give an idea of the relative situation of these rocks, from the top of Hoosac mountain, to a little beyond the Taconic range: although I have no evidence of any such sudden change in the dip as is shown between *b*, and *c*. At *a*, we have mica slate, or gneiss, according to the part of Hoosac mountain over which the section is supposed to pass: the gneiss prevailing at the south part, and the mica slate at the north part of the State. At *b*, we find quartz rock: at *c*, limestone and mica slate: at *d*, talcose slate on the Taconic range: at *e*, clay slate: at *f*, limestone: and at *h*, graywacke, both fragmentary and slaty.

Fig. 120.




This inversion of the dip of the strata is not confined to Massachusetts, and that part of New York east of Hudson river between the same parallels of latitude. It extends as far north at least as Canada; embracing the region between the summit of the Green Mountains and Lake Champlain To the south of Massachusetts, the same series of rocks, with a similar dip, stretch away southwesterly in the direction of the Highlands of New York: thence into New Jersey; and as I have reason to believe from the Geological Reports of the Professors Rogers upon Pennsylvania and Virginia, and of Professor Troost upon Tennessee, the same phenomena occur in those states; and probably still farther south in the Allegany chain of mountains. The width of the strata which exhibit this inverted dip, or are too intimately connected with it to be separated, is in Massachusetts and New York not less than 50 miles; and its length, from Canada to Tennessee, more than 800 miles. Whatever cause, therefore, has produced this anomalous position ot the strata, operated over a vast extent of country, and must have been an immense force.

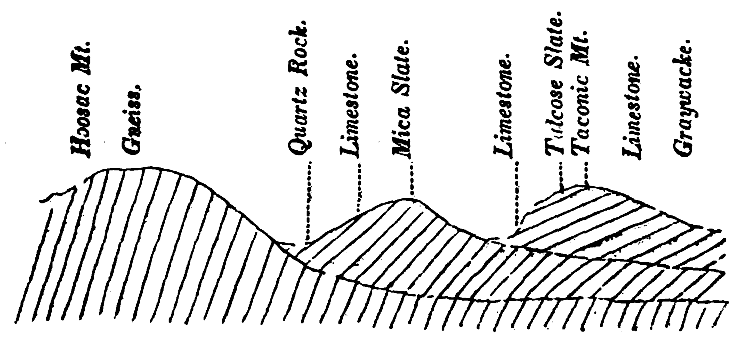
How are these facts to be explained in consistency with the known principles of Geology? I approach this question with diffidence. For although insulated facts like those mentioned above, have been the subject of conversation among some geolegists for the last fifteen years, yet even now they are but imperfectly developed. The Professors Rogers of the Universities of Pennsylvania and Virginia, have undoubtedly collected more facts on the subject than any other geologists in our country. But they have as yet published nothing concerning it, except occasional hints in their annual Geological Reports. In my former Reports I suggested several modes of explaining the phenomena, so far as Massachusetts was concerned; but left the subject in an entirely unsettled and unsatisfactory state. Perhaps I shall do no better now. But I will describe the various suggestions that have been made by myself or others, to elucidate the subject, and leave the reader to judge of their absolute and relative merits.

1. One supposition is, that the secondary divisional planes of the slate rocks have been mistaken for the planes of stratification. If it were only a single formation in which this inverted dip appeared, I should suppose it possible that such a mistake might occur. But here we have gneiss, mica slate, talcose slate, quartz rock, limestone, clay slate, and graywacke, all interstratified; and some of them embracing several distinct varieties; as graywacke, in which we sometimes find a coarse fragmentary variety succeeded suddenly by a slaty variety; and it would be very strange, if at the places where so many rocks meet, we should not discover at some of them that the apparent was not the true dip.

2. Another supposition is, that the true character of the slates and limestones of Berkshire County, and along the western slope of the Green and Hoosac Mountains generally, has been mistaken: that instead of being mica slate, talcose slate, and primary limestone, they do in fact lie above the graywacke, and are more recent. This is the view taken by Professor Emmons; (*Report on the New York Survey for* 1837, *p.* 232.) and although I have the highest respect for his opinion, especially as he has enjoyed superior advantages for examining these rocks, yet I find it impossible for me to adopt his views: and for the following reasons. 1. In all the rocks of Berkshire County, and in the same series of rocks from Canada to Tennessee, no trace of organic relics has been discovered; whereas the graywacke group on which these are supposed to rest, abounds with organic relics. 2. If the rocks composing Saddle Mountain, Lenox Mountain, and the Taconic range, and those in the valleys interstratified with the limestone, are not genuine mica and talcose slates, I know not where such can be found in New England. (Nos. 2064, 2075, 2079, 2097, 2099, and 2149 to 2178.) Yet by this supposition these rocks must be considered as lying much above the fossiliferous rocks near Hudson river. 3. These slates, especially in the southern part of Berkshire County, appear to pass beneath distinct gneiss rock, and this must be regarded as still newer than the slates according to this supposition.

3. A third supposition is, that we are deceived in regard to the position of the older and newer strata; and that the latter do not actually pass under the former, but are arranged as in the following ideal section.

Fig. 121.




This hypothesis supposes that there are several distinct formations superimposed unconformably upon one another, all having so nearly the same dip that we scarcely notice any change as we pass from one group to another. This would be a very extraordinary though a possible case. But the fact is, that as we pass westerly from Hoosac mountain, we find the rocks evidently less ancient, even before we pass over the first interstratified group of strata, viz. the mica slate, talcose slate, quartz rock, and limestone, that lie between the western base of Hoosac mountain, and the western base of the Taconic range. The limestone becomes less and less crystaline and magnesian, and its white colour is more or less lost by the predominance of a dark grey: while

the slates approach nearer and nearer to clay slate. In short, there appears to be a gradual change from older to newer, just as we witness when we proceed outward from a central axis of crystaline rocks. And were the strata to be raised up and turned over, so as to dip westerly at the same angle at which they now dip easterly, it would bring every thing right. In fine, for this and other reasons that might be named, and which are familiar to every one conversant with the rocks under consideration, I expect that every such person will reject this supposition as untenable.

4. The only remaining theory is, that these rocks have actually been thrown over into an inverted position; or rather, have been so contorted by a force acting laterally, that one or more folded axes have been produced. This theory I did, indeed, mention in my Report of 1835: but it then appeared to me too improbable to be admitted. Subsequent reflection and examination have led me to view it in a much more favorable light. I shall therefore, now present the arguments on which it rests.

In the first place, this supposition will explain the anomalous situation of the strata under consideration. I do not feel particularly enough acquainted with the rocks between the Taconic range and Hudson river to give a detailed section. But taking the statements of Professor W. W. Mather, and the Geological Map of Berkshire County and a part of New York, by Professor Dewey, published in the 8th Volume of the American Journal of Science, as my guide, I think the general features of the country between Connecticut and Hudson rivers may be conceived to have been produced in the manner which is elucidated by Figs. 122, and 123. Let us suppose that at an early period in the world's history, the position of the strata between these rivers was as represented in Fig. 122. We may imagine the strata of gneiss to be covered with a deposit of mica slate, and somewhat bent upwards, while upon their western flank are deposits of newer rocks in the following order: Limestone: Mica Slate: Talcose Slate: Clay Slate: Limestone: Graywacke and Clay Slate: marked on the figures by abbreviations. All these deposits, except the mica slate, may be supposed to stop short of the summit of Hoosac mountain. Now while yet the strata were in a plastic state, let us imagine a powerful force to act in opposite directions at the two extremities, viz. at Connecticut and Hudson rivers; where there is strong reason to believe two faults exist. The effect of this lateral pressure would be to bend the strata upwards; and if they were sufficiently yielding, to fold them together, as is shown on Fig. 123. At the same time, there might be an upward pressure from gaseous or melted matter beneath, forcing its way upward, certainly beneath the principal axis, that is, Hoosac mountain, and perhaps beneath other spots. Both these forces, and also that of gravity, would conspire to fold the strata together, as on Fig. 123; and of course to shorten the distance between the

extremities. It is not shortened enough on Fig. 123, to produce all the contortions shown on that drawing. But it must be recollected that the scale of heights is vastly larger than the scale of distances. For while it is more than 50 miles from one end of the sketch to the other, the height of Hoosac mountain is less than half a mile; and yet it is here represented as nearly half as great as the distance from the Hudson to the Connecticut.

Suppose now, that after this folding together of the strata, extensive and deep denudation of the surface should take place, as we know it has taken plaee, over the whole of New England and New York. Imagine the strata to be worn off as deep as the irregular line A, A, and the character and dip of the strata will correspond in general to what we actually find between Connecticut and Hudson rivers along the south line of Massachusetts: Thus, beginning on the west side of the former river, we first strike a narrow deposit of mica slate, leaning a little to the east. Next succeeds gneiss, with a nearly perpendicular dip, till near the west side of Hoosac mountain the strata begin to lean a little to the west. Next we cross a bed of limestone, which may represent the dolomite along the west base of Hoosac mountain: next a deposit of mica slate, as we find it interstratified with the limestone in the valleys of Berkshire. As we approach the Taconic range, we first strike a deposit of more recent limestone, viz. that which is shown on Fig. 122, as lying immediately beneath the graywacke, and which is shown on Fig. 123, as folding over the Taconic and terminating at its eastern base. This represents the less crystaline and often dark coloured non-magnesian limestones of the western part of the County. To this stratum succeeds, along the supposed denuded surface, clay slate, mica slate, and talcose slate; which in like manner fold over the Taconic. At the west base of this ridge, we again cross the clay slate and the limestone; and then we reach a clay slate of a more recent date, shown as lying above the graywacke on Fig. 122; and on Fig. 123, as folding over another axis between the Taconic and Hudson river. Finally, we cross the graywacke, and near the river, the clay slate, the most recent of the strata.

Fig. 122.

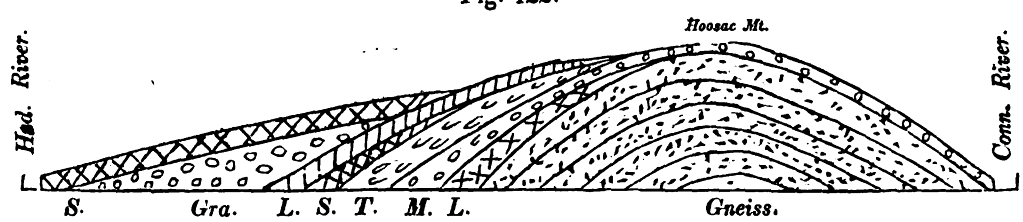
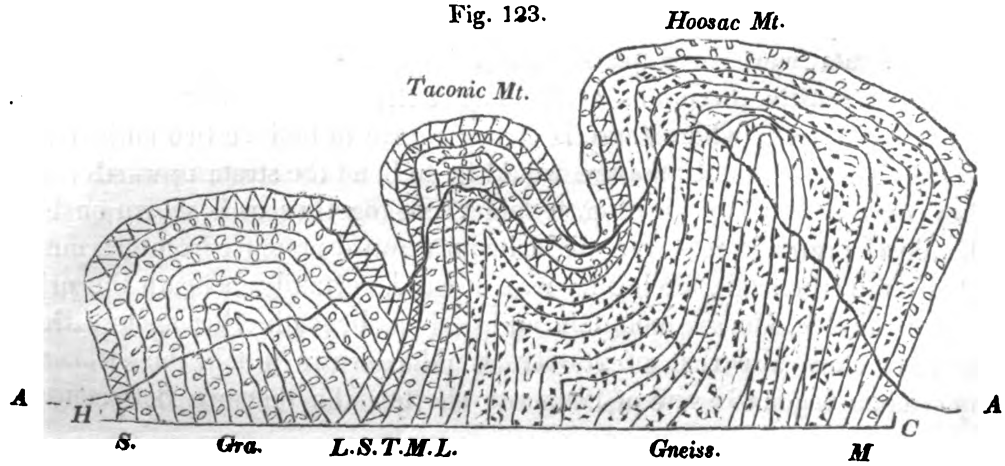



Fig. 123.



I expect, that if the region between the Taconic range and Hudson River be carefully examined, more than one folded axis will be found. But to suppose only one is sufficient to illustrate the subject. On so limited a sketch it is impossible to represent the numerous alternations of strata that occur in Berkshire. But a general resemblance between the sections above given and the actual character of the rocks, is all that is necessary to illustrate the argument.

In the second place, such a supposition explains satisfactorily, why the strata in the valleys of Berkshire have generally a less dip and more irregularity of dip than those upon the mountains. This will be obvious by an inspection of Fig. 123. It will there be seen that the strata might even be horizontal at the bottom of the valleys, and that every degree of inclination might result from denudation; which would of course be very different in different places. I am inclined, also, to believe, that it is in a great measure owing to denudation that the limestone rises in no place but a few hundred feet above the bottom of the valleys. For limestone is much more liable to be worn away than its associated slates. The fact, however, that little limestone is found upon the mountains, seems to me very difficult to explain satisfactorily. In no place have I noticed pure limestone more than 200 or 300 feet above the bottom of the valleys; and the same holds true, so far as I can ascertain, in the same group of rocks from Canada to Tennessee. Hence we may safely infer that the fact results from some very general cause.

In the third place, there are some facts that lead us to believe that there exists in the western part of Massachusetts, extensive fractures, or faults, coincident in direction with the ranges of mountains. One of these is the existence of thermal springs, at Williamstown, New Lebanon, and Mount Washington. For in almost every other part of the world such springs indicate fissures in the rocks, reaching to a gréat depth. Another fact is the extensive dolomitisation of the limestone which has taken place in the county, and which I shall soon describe more particularly. Such a metamorphosis is found almost always to be connected, either with the protrusions of unstratified rocks, or with dislocations of the strata. The former cause cannot be assigned in this case, because unstratified rocks are scarcely found in the county. Now if such extensive fractures do exist in that region, it indicates the operation of some very powerful disturbing agency in early times.

In the fourth place, such a disturbance is readily admitted on a small scale. If a section no larger than Fig. 122, were constructed of yielding materials, and then a force applied at the two extremities in opposite directions, we can readily admit that the layers might be bent into the contortions on Fig. 123. We sometimes see that this has actually been done in the layers of diluvial clay, as shown on Figs. 70 and 71, p. 362, and 363. Nor would the requisite opposing forces need to be of much power to produce such an effect. Probably, however, it would be necessary to admit that a strong pressure from above must accompany the lateral pressure.

In the fifth place, why should we hesitate any more to admit that a similar folding and inversion of the strata would take place over a breadth of 50 miles, and 800 miles in extent, provided we can find in nature opposing forces sufficiently powerful to accomplish the work, and a weight sufficiently heavy to hold the strata in place during the operation. If I could take a series of plastic layers, 6 inches in length, arranged as in Fig. 122, and by a pressure with my hands at the two extremities, produce the flexures on Fig. 123, why would it not be equally easy for a being sufficiently powerful,

to do the same with a series of strata 50 miles broad? Is not the great difficulty which we feel in this case, that we are not familiar with the exertion of such a mighty force as this operation implies? I confess I do not see why the contortions are not as easily made, if there be adequate power, on a large as on a small scale.

Finally, adequate agencies for this work exist in nature, and have often been in operation. I refer particularly to the force that has ridged almost every part of the earth's crust into lofty mountain ranges. We will take for illustration the theory of Elie de Beaumont, that this work has been accomplished by the shrinking of the heated nucleus of the earth, whereby its envelope, becoming too large to wrap closely around the nucleus, sunk down in some places and was forced up in others; so as to be more or less regularly plicated. The parts that sunk by the force of gravity would exert a prodigious lateral force upon the intervening strata, and inevitably force them upwards; and if in a plastic state, the layers must be bent and folded in every conceivable manner. This lateral force would evidently act at a mechanical advantage; and if the mass drawn downward by gravity was thick and large, the force exerted would be prodigious. Suppose for instance that the strata over New England and New York were 5 miles thick, and in a yielding state, from the effects of internal heat. Let this crust become weakened along the lines now occupied as the beds of Connecticut and Hudson rivers, so as to sink down by gravity into the vacancy beneath. What could resist the lateral force which would thus be exerted upon the strata lying between the two lines of depression, and which might be supposed to be pressed down beneath a deep ocean! Suppose they were thus so elevated as to become, say along the present ridge of Hoosac mountain, the highest land in New England or New York. Then this ridge would become the place of least resistance over the whole area; and the strain upon the rocks at a great distance might be more or less relieved by crowding the whole crust towards that line, and thus forcing up the strata there to a great height. And if from any cause the pressure should be the greatest from the west side, it is easy to see that the strata, as they were crowded upwards, might move more to the east than the west, and thus might they fall partly over towards the west, and assume an inverted dip; especially after their upper portions had been worn away.

I might extend the same hypothetical reasoning to the whole of that immense band from Canada to Tennessee, which I have supposed might, in a similar manner, have been subject to this mighty agency. But it is difficult to bring up the mind to the contemplation of the work, even as it shows itself in Massachusetts and New York. Frequently, as I have stood upon some of the loftiest points of the Hoosac and Taconic mountains, have I tried

to realize that all those immense ridges, that stretched away on every side as far as the eye could reach, had been once lifted up and tossed over. And then have I tried to realize that perhaps this same agency may have extended along a belt stretching almost through the United States. And I confess that my mind has staggered under the mighty thought, and I have involuntarily exclaimed, that such a work could have been performed only by Him. who *meted out heaven with a span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance.*

According to the views which have now been suggested, it will follow, that wherever we find the limestone of Berkshire county enclosed between strata of gneiss, it must be regarded as the oldest variety of that rock, or primary limestone. Where it is interstratified with mica and talcose slate, although more recent than that in gneiss, it ought still probably to be regarded as primary. But when we find it above these rocks; (and a part of that in the county, especially along the western side of the valleys, may be of this description, being the remnant of the deposit which once folded over the Taconic, as Fig. 123 will show,) then, as it lies immediately beneath clay slate, it may be what is called primary, or what is called transition, according as we place clay slate in the one class or the other. Still more decidedly transition is that limestone lying between the clay slate and the graywacke in New York; although I believe even in this no organic remains have been found. But after all, I am by no means satisfied that these views are correct; and shall cheerfully abandon them when sounder ones are offered. I have done all that I can to unravel this difficult subject.

### *Impregnation of mica and talcose slates with Carbon.*

A very curious fact has arrested my attention at a few places in Berkshire county, respecting the influence of limestone upon the slates with which it is interstratified. For several feet at least from the junction of the two rocks, the slate is considerably charged with carbon, so as to appear black. The best locality to which I can refer for an example, is at Kent's limestone quarry near the center of New Ashford. The limestone and mica slate here dip to the east about 30°; and the latter rock is succeeded, within a few rods, by talcose slate. And it is a singular fact, which I have mentioned in another place, that I have never seen the real talcose slate lying in direct contact with the limestone; though probably it may be found in this situation. But a band of what I call mica slate always intervenes between the two rocks. I cannot but suspect strongly that this fact has some connection with the impregnation of the slate with carbon; nor can I avoid inquiring whether after all, what I call mica slate may not be an altered talcose slate. An obvious source from whence the carbon might have been derived, is the carbonic acid of the limestone: And yet the heat must have been very intense, or other circumstances favorable, in order to effect the decomposition of that gas. But I will defer any farther remarks upon this point, till I have considered the origin of dolomite: for perhaps we may discover another source whence the carbon was derived.

I have never met with any fact respecting the impregnation of the slates with carbon, analogous to the one above detailed, except in the Report of Professor W. W. Mather, upon the Geology of the eastern part of New York, where it is mentioned that the talcose slate of West Chester and Putnam counties, "at its junction with the gray and whitish limestone, is highly loaded with carbon and pyrites." (*Report for* 1838. *p* 88.) This limestone and talcose slate are a continuation southwesterly of the same rocks in Berkshire county.

## *Dolomitisation of the Limestones of Massachusetts.*

It has been found in Europe that carbonate of lime, or common limestone, when in contact with certain unstratified rocks, or near faults and dislocations, becomes impregnated with silica, alumina, and especially with magnesia. Similar changes have taken place in the limestones of Massachusetts; and a detail of the facts on the subject becomes important.

As a general fact it may be stated, that where our beds of limestone occur in gneiss, or in sienite, and hornblende rock passing into greenstone, they are more or less magnesian and charged with silica and alumina; as will appear from the Table of Analyses on page 80. At Newbury and Stoneham the beds are in sienite, and at Smithfield and Newport, Rhode Island, they are near either sienite or granite; and at all those places the limestone is more or less charged with magnesia: although the specimen analysed from Newbury shows but little. But that specimen was by no means a fair representative of the limestone there. The beds in Bolton, Boxborough, Chelmsford, Littleton, Natick, Concord, Middlefield, Becket, and the south part of Tyringham, are also magnesian, with one or two unimportant exceptions, as at Concord, and some of the specimens at Natick: and most of them are loaded with earthy impurities. In very few of these localities do we find any unstratified rock in immediate contact with the limestone, although the gneiss containing it is frequently traversed by granite veins and is itself highly granitic.

The Table of Analyses will show, that some of the fetid limestone of the new red sandstone in Springfield and West Springfield, especially the septaria, is magnesian. But I can hardly believe that in this csse there is a connection between this fact and the unstratified rocks. For these are usually distant from the limestone at least a mile or two, and in the only case where they are in contact, at Paine's quarry in West Springfield, the rock is not magnesian.

But the most perfect and extensive example of dolomitisation in Massachusetts, may be found in Berkshire County. Along the western base of Hoosac Mountain, that is, in the eastern part of the valley of Berkshire, dolomite prevails extensively. A good deal of the rock is a pure crystaline double carbonate of magnesia and lime; as in Dalton, Lee, Tyringham, &c.: and generally it is but little impregnated with earthy ingredients, as may be seen from the Table of Analyses. The geological map and the sections will show, that although this magnesian limestone is not far removed from gneiss, yet it is in fact interstratified with mica slate, and perhaps quartz rock. As we pass westerly in the county, the limestone becomes less and less magnesian. Yet in all parts of the county, we find it occasionally dolomitic: and frequently one layer or stratum is charged with magnesia, while another, not far distant, is almost free from this earth.

Throughout the whole of the limestone district of Berkshire, there are scarcely no traces of the existence of unstratified rocks. But if the views that have been presented respecting the folding and overturning of the strata there, are an approximation to the truth, we should expect the existence of extensive faults. And by consulting Fig. 123, it will be seen that the strata at the western base of Hoosac Mountain must have been powerfully contorted; and, therefore, they would be liable to extensive fractures, just along the line where the dolomite is most abundant.

From these facts, therefore, I think we can safely say, that all the cases of dolomitisation in Massachusetts, occur either in the vicinity of a fault, or of unstratified rocks, or in the midst of gneiss, where the evidence of the powerful action of heat in the induration of the limestone, and the obliteration of its stratification, is as great as results from the presence of unstratified rocks. The facts in this State, then, are in correspondence with those in Europe on the same subject.

But what is the mode in which this metamorphosis has taken place? The theory is, indeed, involved in some difficulties. But all geologists will agree that heat is the principal agent. In some instances it appears highly probable that magnesian limestone has been deposited directly from thermal waters: as was probably the case with the septaria of Springfield. But generally in Massachusetts, it was probably produced by gaseous sublimations, chiefly of carbonate of magnesia, which penetrated the rock after it had been softened by heat, so as to be permeable. In some cases the impregnation was so perfect and thorough, that the rock was entirely converted into crystaline dolomite. In other instances, the work was only partially accomplished. This will explain why it is, that we find so many different proportions of magnesia in limestone, even in specimens lying within a few feet of one another. And it explains, also, why some beds of limestone have almost entirely lost all traces of stratification, and others retain but slight marks of parallel divisional planes. In Massachusetts I think it is true, that the marks of stratification become obscure, nearly in proportion to the amount of magnesia which the rock contains: and when a perfect double carbonate is formed, it is as much unstratified almost as granite or trap. In such cases I doubt not but an almost perfect fusion has taken place in the limestone, though under strong pressure.

If we suppose that dolomitisation has resulted from the sublimation of carbonate of magnesia, it is not difficult to imagine how some of that salt might be decomposed, the magnesia become a silicate, or some other salt, and the carbonic acid impregnate the slaty rocks which enclose the limestone. Here it might be decomposed, its oxygen go to peroxidize the iron and other metallic substances in the slate, and the carbon remain disseminated as we find it. The carbonic acid of the lime might, also, have been sometimes

driven off and have undergone the same change; and in both these ways, we see how the slate might have been charged with carbon, and the silicates of lime and magnesia, which form several minerals, have been produced. The silica and alumina found often in dolomitised limestone, may have been introduced by means of intensely heated water or steam.

The fact mentioned on a preceding page, that I have always found what I call a band of mica slate lying between the limestone and the talcose slate, leads me to make a suggestion respecting another mode in which perhaps some magnesia might have been procured for the process of dolomitisation. The most important points of difference between the composition of talc and mica consists in the large quantity of magnesia in the former, and of potassa in the latter. Now is it not possible, that by means of heat and galvanic action, the magnesia might have been abstracted from the talc and transferred to the limestone; and the remaining ingredients of the talc have seized upon a portion of potassa, that might be supposed to exist in the rock, and become converted into mica, so that for a certain distance on each side of the limestone, only mica slate should be found? That such chemical changes would be possible will be admitted: but whether they are probable, is more than I shall undertake to say.

Such are some of the marks of the powerful action of internal heat upon the rocks of Berkshire county. To the geologist and the chemist they are as striking and convincing almost, as the lava and the smoke of Vesuvius are to the common observer. But though this agency must have been powerful when vast masses of limestone were melted and converted into dolomite, and huge masses of slate impregnated with carbon, yet the only agency now exerted by these almost smothered Solfataras, is to raise a few degrees the temperature of two or three springs.*

### *Mineral Contents of the Berkshire Limestone.*

By far the most important mineral connected with the limestone and mica slate of Berkshire County, is the hydrate of iron, or limonite. The localities, amount, and economical value of this ore, have been so fully pointed out in the first part of my report, that I need add nothing more in this place It only remains to consider the true situation of this ore in the rocks.

I have not been able to find the actual junction of this ore with any rock except diluvium. But Foss' bed of hematite, in Dover, New York, six miles west of Housatonic river, lies upon the east side of a narrow valley, bounded on both sides by mica slate. The slaty structure of the ore is quite distinct, and the dip and strike correspond to those of the slate close by. At the large deposit in West Stockbridge, the same thing may be seen: although nothing but diluvium, or perhaps alluvium of disintegration, now appears at the sides of the bed. A few years since I took a sketch of the south wall of this excavation, and Section M. on Plate 55, will show its appearance. It will be seen that the slaty structure of the ore has the same large easterly dip

*I wish that the temperature of the springs generally in Berkshire County, could be accurately compared with those of other parts of New England. For I am not without a suspicion, that the former might be found a little more elevated than the latter; and thus show that the internal agency spoken of in the text, is yet operating more widely than is supposed.

which is common in the slate of that region. In several places, as in Richmond, beds of limestone lie very near the ore; but the actual junction is concealed. Upon the whole, I infer that this ore forms beds interstratified with the mica slate and limestone: but I have no evidence that it lies exclusively either in the slate or the limestone. Perhaps it may exist in both, or lie between them. This point will be settled when the beds have been explored deep enough to reach the bottom of the soil around the ore. Yet if we admit that the ore forms beds in either of these rocks, it is of little consequence in an economical point of view in which rock it occurs. If it does form beds, then we may look upon the mines as inexhaustible; since there is no probability that their bottom will ever be reached.

In the hematite bed of West Stockbridge, we sometimes meet with a fibrous variety of pyrolusite. It occurs, also, at other deposits of hydrate of iron, and especially in Bennington, Vermont, where large quantities have been obtained. Since the first part of my report was printed, I have received specimens of this ore from the northwest part of Sheffield, near the base of Mt. Everett, where an exploration is now going on in search of it. It exists there, so far as I can learn from the description of others, only as a loose mass in soil; or rather, just as the beds of hematite occur in other parts of Berkshire. Yet limestone is found in place near the spot. I believe the quantity of ore obtained, has not yet been large. I have marked the locality upon the Geological Map.

At several of the ore beds in Richmond, and especially at one owned by Mr. Gates, occurs an almost pure hydrate of alumina; which Professor Torrey has named Gibbsite, in honor of Col. George Gibbs, an early cultivator and munificent patron of mineralogy in our country. It usually occurs mammillary and stalactical, of a white color. But in the collection of Mr. Anthony Clark of West Stockbridge, I was shown specimens of what appears to be Gibbsite, crystalised in delicate needles, disposed in tufts upon mammillary masses of the same. This was from the ore bed in that town, and No 1705 is a poor specimen of the same. I cannot make out the form of the crystal from any specimen in my possession: but I think it may be done with Mr. Clark's specimens. This mineral is said, also, to have been found at Lenox. No. 61 will give an idea of its usual appearance. Mr. Clark also gave me a specimen of mammillary hydrate of iron, covered with a beautiful dendritic impression, probably of manganese. (No. 1691.) The compact carbonate of iron, which is perfect Sphaerosiderite, from the same ore bed, (No. 1689,) has been sufficiently described in the first part of my report: as has also the galena and pyrites from Alford (No. 1984)

White augite, in distinct crystals, is found in the dolomite of Berkshire county. I have met with it in Tyringham; (No. 1974,) but it occurs in much greater abundance in Canaan, Conn. Tremolite is still more common there, and in Berkshire. In Sheffield the fibres are sometimes more than two feet long, and embrace crystals of iron pyrites; and there it has been mistaken for petrified wood. Sometimes the fibres are fine and delicate In Great Barrington it occurs in distinct bladed crystals: but the best locality I have found of these crystals, is half a mile, or a mile, southwest of the meeting house in Lee, at a lime quarry. The crystals are beautifully distinct, although seldom showing any regular terminations. (Nos. 1976, 1977.) Tons of this mineral might be obtained here in a few hours. I have noticed tremolite also, at the limestone bed in the S. E. part of Becket. It has been said that yellow tourmaline occurs in the limestone of this county. Perhaps it is only a yellow variety of tremolite; such as I take No. 1980 to be, from Lenox. In a few instances I have found a mineral, as in Becket and Adams, which I take to be sphene. (Nos. 1981, 1982)

On the farm of Mr. Phelps, in the south part of Williamstown, occurs a fine locality of crystalized quartz. It forms drusy cavities, a few inches wide; and some of the specimens obtained there are very beautiful. (No. 1986.) In the same vicinity, on land of Deacon Torrey, the limestone and quartz are sometimes coated with a thin film of carbonate of copper. Crys-

talized calcareous spar is frequently found connected with this limestone in various forms. I several caverns in New Marlborough, Lanesborough, &c., we find stalactites; but none of them are remarkable. (No. 1978.) Agaric mineral is said to exist in a cavern in West Stockbridge, and calcareous tufa is said to be deposited by some springs in Williamstown.

### *Theoretical Considerations.*

The question whether all the beds of limestone on the globe have originated from the remains of animals, or in part resulted from chemical deposition, will probably be better understood when some preliminary facts have been stated in the Fourth Part of my Report. I shall, therefore, in this place, only make a few remarks on the probable metamorphic character of most of the deposits in Massachusetts.

It might be supposed that where limestone occurs in unstratified rocks, as at Newbury and Stoneham, its origin must be igneous. But I have every reason to suppose that in these cases the sienite is only a portion of a gneiss formation, which has undergone fusion to a great degree. For portions of the rock still retain a slaty or stratified structure. Hence the limestone may also have formed originally stratified beds in the gneiss and been deposited from water. The same may be said of the tubercular masses, or beds, of this rock, found in gneiss. In a few of these, however, as on the Western Rail Road in Becket and Middlefield, at the mouth of Cole's Brook, we find a distinct stratification; and hence it is reasonable to infer that originally they were all stratified; and have been so powerfully heated afterwards, as to nearly destroy the parallel divisional planes, and in fact to form *unstratified limestone.* Professor Emmons supposes that all primary limestone ought to be regarded as an igneous unstratified rock, like granite. And he has pointed out many curious facts respecting the occurrence of such rock in as distinct veins in granite as any of the unstratified rocks can exhibit, in St. Lawrence and Essex Counties in New York. (*Report on the Survey of New York, for* 1838, *p.* 196.) But if the limestone imbedded in gneiss ever shows a distinct stratification, as I think is the fact at the locality above mentioned, is it not a strong presumptive evidence that all these beds in gneiss were originally in the same condition? The phenomena of dolomitisation in Berkshire County, throws light on this subject. For we there find all possible intermediate conditions between a stratified and unstratified structure, corresponding generally to the amount of magnesia in the rock: the unstratified masses being generally pure dolomite; as we might expect; since the more perfect the fusion, the better the opportunity for the magnesia to be introduced. I have met with no cases in Massachusetts in which limestone exists in veins like those of granite, sienite, and trap: but had the fusion of the rock been more perfect, I see not why veins might not have been produced under a

pressure sufficient to retain the carbonic acid. And yet, I am not prepared to say that veins of carbonate of lime may not have been produced by igneous action alone without any previous organic agency: but I must consider the conclusion probable, that all the limestones of Massachusetts were originally deposited through the agency of water, and subsequently subjected to a powerful metamorphic agency.

### 9. QUARTZ ROCK.

Among the older rocks geologists have not been able to discover any uniform order of superposition; although each one of them is most likely to be found in a particular connection. But the same rocks are also found in several other connections, so as to render all attempts to fix their exact place in the scale unsatisfactory. Our rocks are as unmanageable in this respect as those in Europe, but no more so; showing that the same general causes have produced them on both Continents. I have already shown that our limestones are of various ages, and the same is true of quartz rock, hornblende slate, and some others. Amid this great uncertainty, as to the place in the series which the older rocks ought to occupy, it is not easy to decide what is the best order of describing them. It will be observed that I do not follow exactly the same order in the account of the rocks which I am now giving, as is followed in the tablets attached to the Map. The order which I now follow, and which agrees with that given, in the Tabular View of the rocks on page 303, accords, as nearly as I can determine it, with the order of natue: whereas on the Map, I was obliged to have some reference to convenience of exhibition; one of the groups being miscellaneous.

### *Lithological Characters.*

Quartz rock was first described by Dr. Macculloch; and its chief ingredient, as its name implies, is quartz. But it takes into its composition, mica, feldspar, and sometimes blue schistose clay. The following varieties are found in Massachusetts.

1. *Pure Quartz.* This exist in several states. First, hyaline, white: generally in beds in mica slate. Secondly, compact, white, or reddish, or dark blue; in beds in argillaceous slate. It is quite obvious that this blue variety has, in some way or other, been coloured by the slate; either when first deposited from aqueous solution, or when subsequently melted, if it ever has been, by heat. Thirdly, coarse, granular, color gray, or reddish. These are the most common varieties. Fourthly, fine, granular, or arenaceous; sometimes disintegrated so as to form a beautiful white sand. (Nos. 545 to 565.)

2. *Granular Porous Quartz, or Pseudo-Buhrstone.* In the west part of Washington is a porous quartz, which has been considerably employed as a substitute for the French Buhrstone, as millstones. It does, indeed, a good deal resemble buhrstone, except that it is more uniformly porous, and the quartz has more of that brittle character and hyaline aspect, that are exhibited by this mineral in the oldest rocks. It also sometimes contains mica, and fragments of hornblende and feldspar. It was not till recently that I was able to ascertain the origin of this rock. *I find it to be a variety of gneiss rock, whose feldspar has decomposed and disappeared;* and in which quartz was greatly the predominating ingredient. No. 2284 exhibits this rock before the decomposition of the feldspar, and No. 567 its appearance when that is gone. In the west part of Washington, near the Housatonic, 4 or 5 miles south of the spot where millstones are prepared, these rocks may be seen in all stages of the process between the gneiss and the buhrstone. As we pass from the river up the hill eastward, we first find in perpendicular strata, a con-

glomerate quartz rock; next a narrow stratum of the buhrstone passing into the gneiss; next mica slate; then gneiss; and all within less than 80 rods. This spot lies nearly east of Lenox center: but being covered with thick woods, through which a considerable brook passes, it is difficult of access, and observers are apt to pass it unnoticed. But I apprehend we have a key here to the somewhat difficult formations in the west part of Washington.

I am unable to perceive why the feldspar of this gneiss should so easily decompose. It usually leaves behind a coating of a yellowish powder; which, however, does not look like a hydrate of iron: and it would be interesting to have this feldspar carefully analyzed to ascertain its composition.

3. *Quartz and Feldspar*; the former in much the largest quantity. This variety usually occurs in connection with gneiss, and not in large quantity. (Nos. 571, 593, 600.)

4. *Quartz and Mica.* This differs from mica slate, only in the predominance of the quartz. Usually this mineral is greatly in excess: but occasionally the quantity of mica increases so much that it is impossible to say of particular specimens to which rock they ought to be referred. In such cases I have taken into consideration the character of the surrounding region. If mica slate predominates, and there be not an actual passage into decided quartz rock, I have thought it useless to describe the rock as quartz rock, even if for a considerable extent the quartz predominates. Such cases as this are common in the mica slate range extending from the mouth of the Merrimack to Connecticut. And on the other hand, if quartz rock predominates, an occasional excess of mica in some of its strata has not prevented me from considering the whole as quartz rock.

The mica in this variety is arranged in a parallel position, and it produces a schistose structure; though sometimes the laminæ are so thick that they ought rather to be regarded as strata. In other instances, the schistose layers are extremely tortuous and very distinct from the stratification. I have observed this circumstance only in Berkshire County, as in Lee. (Nos. 572 to 580; and 587 to 592.)

5. *Quartz and Talc.* Some of the talcose slate in Hawley, Plainfield, &c., occasionally becomes a slaty arenaceous quartz, with seams of greenish talc. (Nos. 581 to 583.) Its color is white, and this rock, in Hawley and Rowe, seen at a distance, resembles gneiss. It is obviously a member of the talcose slate formation; and it may be questionable whether it ought not rather to be described in connection with that formation.

6. *Quartz and Hornblende.* Instead of talc, the white arenaceous quartz described under the last variety, sometimes contains numerous distinct crystals of black hornblende. (Nos. 584, 585.) It forms a beautiful rock, and if it would admit of a polish, might be employed for ornamental purposes. It is less abundant than the preceding variety. In the gneiss formation, there is a variety in which greenish hyaline quartz contains flattened imperfect crystals of actynolite. (No. 584.)

7. *Quartz and Argillaceous Slate.* I have observed this only in Bernardston, in connection with the fossiliferous limestone. (No. 601.) The quartz is white and blue, and exhibits a brecciated structure. It was probably colored by the slate; but very few fragments or layers of slate are now visible.

8. *Quartzose Breccia.* This consists of angular fragments of granular quartz, cemented by oxide of iron; or of fragments of mica slate, surrounded by radiated quartz. The variety found in bowlders in Leverett and Amherst, (I have no doubt that the bed from which they were derived is in Leverett,) contains but very little iron, scarcely more than enough to give a part of the fragments a reddish hue. (Nos. 602, to 608.) Another variety I have found in Amherst, in

connection with the gneiss formation, in which the cement is magnetic oxide of iron. But the most interesting variety exists in numerous bowlders along the western slope and base of Hoosac mountain. It consists of angular fragments of white and reddish granular quartz cemented by brown hematite. (Nos. 604 to 606.) In the cavities the hematite is often iridescent and mammillary; and the coat investing the fragments, fibrous. The largest bowlders of this rock that I have seen, (six to eight feet in diameter,) occur on the Pontoosic turnpike from Pittsfield to Springfield, in the south part of Dalton, at the foot of the Hoosac range. But I have never found this rock in place. It may be that the loose fragments have all proceeded from a huge vein of this breccia. But from their size and abundance, I rather presume that this rock will be found as a bed in the common granular quartz of the vicinity. I found one bowlder of this rock ten inches in diameter, in Southampton, only two or three miles from Connecticut river; affording another proof of a northwesterly diluvial current in former times.

Professor Dewey remarks, that in Great Barrington and Sheffield the fragments of quartz are united by a cement of quartz.

The most common gangue of the lead and manganese ores in Hampshire and Franklin Counties, is quartz. In a majority of cases it is radiated quartz investing nuclei of micaceous slate. Thus is produced a very curious kind of brèccia. (No. 608.) And since these veins are sometimes six or eight feet thick, the quantity is great enough to deserve a notice in this connection.

9. *Quartzose Conglomerates.* This consists of a paste of quartz and mica, in which are imbedded numerous distinctly rounded pebbles of granular or hyaline quartz. (Nos. 609, 610.) It possesses as completely the characters of a conglomerate as any of the puddingstones of the secondary formation. I have never found it in place; and suspect that it underlies the graywacke west of the Taconic range. Its bowlders are not uncommon on the west slope and the top of Hoosac mountain. In Windsor I found them unusually abundant. I have even found small bowlders in the Connecticut valley, in Deerfield. It appears to be identical with the Conglomerate Quartz Rock of Macculloch. (*Geological Transactions, Vol. I. p.* 60. *Second Series*) The size of the imbedded pebbles is usually about an inch. It greatly resembles the rock that constitutes the first ridge of the mountain range on the east side of Wyoming valley, in Wilkesbarre, Pennsylvania; and which there underlies the anthracite coal formation.

I have already alluded to another variety of conglomeritic quartz rock which is found in the west part of Washington (possibly in Lenox,) connected with gneiss rock. It forms the west side of the hill, and passes first into the gneiss that produces the buhrstone, then into mica slate, then into common gneiss, as we go eastward up the hill. This rock is composed of tolerably distinct pebbles of granular gray quartz about the size and having somewhat of the elongated shape of almonds. The cement seems to be a mixture of comminuted quartz, feldspar, and a little mica. Although the pebbles are so much rounded that they must be regarded as of mechanical origin, yet the attrition does not appear to have been as thorough as in some of the more recent conglomerates. The situation of this rock requires us to regard it as deposited towards the close of the period when the gneiss was deposited or immediately after. In the fragments that compose gneiss we see evidence of some degree of mechanical disturbance: but in the production of this rock, that disturbance must have been still greater. (Nos. 2030, 2031.)

## *Topography of Quartz Rock.*

On the Map I have represented all the quartz rock in the State (excepting that connected with the graywacke,) as associated with mica slate, talcose slate, or gneiss. It is also more or less connected with other rocks; as with Limestone in Berkshire, and with argillaceous slate in Bernardston. But in all other cases, except in regard to gneiss and mica slate, it is little more

than a juxta-position of the two rocks; whereas the quartz rock alternates with, and passes imperceptibly into, gneiss and mica slate. And in fact it might be regarded very properly as a member of the gneiss and mica slate formations.

The range of mica slate extending from Webster to the mouth of the Merrimack, often passes into genuine quartz rock, and generally contains a large proportion of quartz. In the south part of this range, in Webster especially, I noticed quartz rock to be abundant.

The gneiss formation on the east of this mica slate, especially near the south part of Worcester County, is associated with extensive strata of quartz rock. In Sutton, and the vicinity, the latter occupies a considerable part of the surface; and there I have delineated this rock on the Map extending to Uxbridge. I have noticed it in several of the towns northeast from Sutton, interstratified with gneiss and hornblende slate. In the eastern part of Franklin County, in New Salem and Warwick, I have met with it in strata of a few feet wide interstratified with gneiss.

Along the western border of the great gneiss range of Worcester County, is another narrow stratum of quartz rock, in some places associated with the gneiss, sometimes with hornblende slate, and sometimes with mica slate. Mica slate is commonly associated with this rock north of Leverett. On the opposite side of Connecticut river, in Northfield, Mass. and Vernon, Vt. quartz rock forms one of the members of a series of mica slate passing into gneiss, hornblende slate, and argillaceous slate. In Vernon it is liable to disintegration and has been employed for the manufacture of glass. In Bernardston, where it approaches the clay slate, as already remarked, it occasionally takes portions of that rock into its composition. But generally in Leverett and Northfield, it is that variety which contains mica. In Granby and Palmer, it is connected with hornblende slate and mica slate.

Berkshire County, however, contains the principal repository of quartz rock. It is there interstratified frequently with gneiss and mica slate, especially along the eastern side of the valleys of that County; as in Tyringham, Great Barrington, and Sheffield. It accompanies the gneiss also, in Savoy and Cheshire. In the former place, not much west of the middle of the town, the rock is disintegrated, as it is in Cheshire, from whence it is obtained for the manufacture of glass. In Savoy it occurs near the top of Hoosac mountain; but probably Bald Mountain in North Adams and Clarksburg, is the highest mountain composed of this rock. In the south part of the County is Monument mountain, a thousand feet above the sea, composed of granular quartz. Several other ridges less elevated are made up of this rock.

In connection with the gneiss in the southeastern part of the State, it may be remarked, that quartz rock occurs in considerable quantity, as I have noticed in several places, having an agatized structure. That which I found in Rochester, is quite beautiful, a polished specimen of which may be seen in the Collection. (No. 1103.) This variety is somewhat abundant.

## *Dip, Direction, and Character of the Strata.*

It requires in many cases careful attention to discern planes of stratification in the purely granular quartz of Berkshire County. They are never, however, wanting for any considerable extent. And frequently there exist divisional planes producing joints or rhomboidal masses. The same is true of the quartz in many other parts of the State; as in Leverett, Northfield, Sutton, &c. (Nos. 577, 2007, 2009.)

| | *Strike.* | *Dip.* |
|---|---|---|
| N. Adams, | N. and S. | E. 25° |
| Clarksburgh, Bald Mt. | do. | E. 20° to 30° |
| Williamstown, Bald Mt. W. Base. | do. | E. 45.° |
| do. 1-2 mile S. of College. | do. | E. 30° to 40° |

| | *Strike.* | *Dip.* |
|---|---|---|
| Washington, W part Quarry. | do. | E. 90° nearly. |
| do. near the same Quarry. | do. | W. 10° to 15.° |
| Lee, N. part. | do. | E. 45.° |
| Beartown Mt. S. Side. | N. W. and S. E. | N. E. Small. |
| New Marlborough, Umpachena Falls. | Horizontal. | |
| Windsor, N. W. part. | E. and W. | N 25.° |
| Bernardston and Northfield, W. of Connecticut River. | N. and S. | E. 20° to 60.° |
| Northfield, South Mt. | do. nearly. | E. large. |
| Palmer and Monson, near R. Road. | N, 25° E. | W. 60° to 70.° |
| Southborough. | E. and W. nearly. | N. large. |
| Oxford and Webster. | N. and S. nearly. | W. 20° to 45.° |
| Between Webster and Franklin. | N. W. and S. E. | N. E. |
| Sutton. | E. and W. | W. 30° to 35.° |
| Uxbridge, S. W. part, Galena Vein. | N. E. and S. W. | S. E. 30° to 60.° |
| do. Melville. | N. W. and S. E. | N. E. |
| Cumberland, R. I. S. part. | N. E. and S. W. | N. W. large. |

In general, quartz rock exhibits great distinctness and regularity of stratification, particularly the variety containing mica. Where the mica is in small quantity, the thickness of the strata is considerable; but as the mica increases, the layers are thinner, until at length the rock becomes schistose. At the quarry in Washington, near the buhrstone locality, the stratified structure is beautifully exhibited; and it results from a minute quantity of mica, in scales scarcely visible to the naked eye.

In general the dip and strike of the strata of this rock correspond to those of the gneiss and mica slate with which it is connected. In Berkshire I have already remarked that the direction is usually north and south, and the dip east, at rather a small angle.

The quartz rock in Northfield and Bernardston, west of Connecticut river, dips from 20° to 60° east, and runs north and south. East of the river, its dip approaches 90° east. In Southborough its direction is nearly east and west, and its dip northerly and large. In Oxford and Webster, its direction is nearly north and south, and its dip from 20 to 45° west; though in the west part of Oxford I noticed a dip of 10° easterly, the rock being interstratified with gneiss. In Sutton the dip is from 30 to 35° north, corresponding to that of the gneiss in the vicinity.

## *Mineral Contents.*

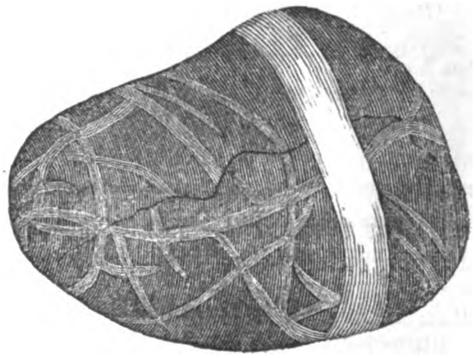
Scarcely any rock in Massachusetts, is so destitute of simple minerals as this: unless we include in it those metallic veins of which quartz is the gangue. But these may more appropriately be described under granite; in which rock these veins for the most part occur. Hematite iron ore, forming the cement of the quartzose breccia in Dalton, is the most interesting mineral in the quartz rock. Sulphuret of iron, also, has been observed in small quantities in that quartz rock which is associated with talcose slate in Hawley, &c. In Pittsfield, Worthington, &c., masses of quartz are found of a yellowish color, and appear to be genuine ferruginous quartz. Sometimes this quartz passes into yellow jasper, and also into chalcedony and hornstone as at Dalton, Tyringham, &c. On page 194 I have described a narrow vein of magnetic oxide of iron on Beartown Mountain, said to occur in quartz rock. The argentifera galena in Uxbridge, already described, is found also in quartz rock. This ore has recently been analysed by Dr. Charles T. Jackson, and he finds it to contain 0.355 per cent of silver; or a little more than 7

pounds to the ton. (*Report on Rhode Island, p.* 73.) This is a larger proportion than is usual: but as the ore is in small quantity, it is doubtful whether it can be worked to advantage.

### *Veins in Quartz Rock.*

In a few instances, as at the quarry of quartz rock in Washington, several times spoken of, veins of granite may be seen. But generally the veins in quartz rock are quartz; the vein being usually white and opaque, and the rock a mixture of gray quartz and mica,—the latter mineral existing, however, in very small proportion. The following is the sketch of a bowlder of about eight inches diameter, found in Amherst. The principal part of it is gray quartz traversed by numerous veins of white quartz.

Fig. 124.



*Quartz veins in quartz rock.*

### *Theoretical Considerations.*

The regularity of the stratification in quartz rock, and the fact that silica is soluble in water, have disposed geologists, in all cases where it is possible, to impute to this rock an aqueous origin. But like all the older rocks it appears subsequently to have been subjected to heat of a greater or less degree of intensity, whereby it has sometimes been rendered compact. And no doubt in this way some siliceous sandstones have been converted into solid quartz: as in the Isle of Sky, in Scotland, where trap comes into contact with the sandstone.

A complete theory of the formation of that variety of brecciated quartz, which in Dalton is cemented by hydrate of iron, it is not easy to form. The chief difficulty seems to be, to imagine how the quartz was broken into such numerous angular fragments: for after these fragments were piled together, it is not difficult to conceive that the interstices might have been filled by the iron from solution in water, or by sublimation from heat.

The conglomerate quartz rock originated probably like other conglomerates; that is, we must first suppose an abrasion of existing strata, and then

a consolidation of the materials thus worn off, either by heat or simple desiccation. In the present case, heat was probably an important agent. Otherwise I know not how to explain the marks of a crystaline structure which it exhibits; as much, indeed, as the oldest slates.

## 10. MICA SLATE.

It is usual to place this rock next to gneiss, or as the second in respect to age among the stratified rocks. And in Massachusetts it is not unfrequently associated with gneiss. But it is also associated with every other rock, as high in the series at least as argillaceous slate: I mean in a conformable position. Hence I have thought it best to introduce it before talcose and hornblende slate and serpentine; because these latter rocks, in Massachusetts, are usually connected with gneiss or the oldest varieties of mica slate.

### *Lithological Characters.*

It is hardly necessary to remark, in respect to a rock so common and well known, that its essential ingredients are quartz and mica: and the anomalies of composition are fewer in this rock than in most others; although the varieties of aspect are numerous. However, it is necessary that the mica should be the predominant ingredient, in order to constitute a rock mica slate. But in this case we must look to the whole mass of the rock, rather than to hand specimens: for single specimens may often exhibit the quartz in excess, and yet be regarded as mica slate. The following varieties of this rock I have found in Massachusetts.

1. *Quartz and Mica:* the former granular and laminar; the latter in distinct scales and highly glistening. This variety is associated with the oldest rocks, as granite and gneiss; and is obviously more highly crystaline than the other varieties. The longitudinal arrangement of the mica gives this variety sometimes a fibrous appearance. (Nos. 614 to 626)

2. *The same, containing a small proportion of Feldspar,* and thus passing into gneiss. (Nos. 627 to 636.) It is only when the mica greatly predominates that this rock can with any propriety be denominated mica slate.

3. *Amphibolic and Garnetiferous Mica Slate.* This variety takes into its composition in large proportion, hornblende or garnets; usually both. From the fact that those minerals are commonly found together, I have made only a single variety include them both. (Nos. 642 to 645.)

4. *Staurotidiferous Mica Slate.* In this rock the mica is in very fine scales, and has the general aspect of argillaceous slate; except that when the strata are viewed edgewise, they exhibit a striped appearance, in consequence of numerous layers of staurotide, which appear to be coextensive with the layers of the rock. I should not have regarded this mineral as of importance enough to constitute a distinct variety of mica slate, did I not know that extensive ledges, like the rock just described, extend nearly across the whole of Massachusetts, through the towns of Norwich, Chesterfield, Goshen, Hawley, and Heath; and on the east side of Connecticut river,

it has been traced, with some interruptions, from near Long Island Sound to Franconia, New Hampshire, a distance of nearly 200 miles. Where it crosses Massachusetts, however, it is but imperfectly developed. (No. 646.)

I wish here to remark, that when I coin a new term to prefix to a variety of rock, it is rather for the sake of giving a laconic definition, than in the wish or expectation that it will become a permanent name for the rock. Indeed, mere varieties need no distinct names, except when an attempt is made to give a logical account of a formation.

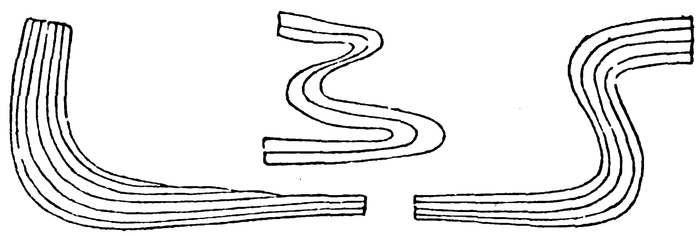
5. *Spangled Mica Slate.* The basis of this singular rock is the same as in the last variety; and the two are associated in Chesterfield, Goshen, Plainfield, &c. Through this base are disseminated numerous thin foliated plates of a deep brown color, resembling mica somewhat, but almost entirely destitute of elasticity and brittle. Their length, (rarely more than a quarter of an inch,) is usually twice as great as their breadth, and there is a decided polarity exhibited in their arrangement: that is, their longer axes all lie in the same direction, and the surfaces of the plates in the same or in parallel planes; so that light is reflected from many of them at once when the specimen is held in a proper position, and thus a beautifully spangled appearance results. Not being confident as to the nature of this mineral, I have given the rock a designation which indicates merely this obvious property. These spangles are pretty uniformly diffused through the mass, and their surfaces rarely coincide with the layers of the slate. (Nos. 647 to 650.)

I have already described this rock as one of the varieties of metamorphic slate in the eastern part of the State. In Plainfield it is sometimes jointed. (No. 649.)

6. *Argillo-micaceous Slate.* This exists wherever the mica slate passes by gradation into clay slate: and such places are numerous in Massachusetts. It exists also, in connection with the two last varieties, in the range of slate passing through Chesterfield, &c.; where the strata are perpendicular, and have a broad range of decided mica slate on the east, and a similar extent of talcose slate, hornblende slate, and gneiss, on the west. It does not, however, in this case actually pass into clay slate. And I believe it will always be found to consist of fine scales of mica, closely compacted, so as to give it an argillaceous aspect. This rock sometimes contains large beds of white quartz, which is frequently fetid. (Nos. 651 to 667.)

7. *Arenaceous Mica Slate.* In this variety the quartz is gray, in fine sandy grains, and diffused through the whole mass, not lamellar. (Nos. 668 to 712.) The mica is in fine disseminated scales; although the plates are usually parallel to one another. The mass is usually imperfectly schistose, though more regularly stratified than most other varieties; and sometimes there exist oblique divisional planes. Ordinarily it is not so much contorted in its layers as the older varieties; but an intermediate variety is perhaps of all the mica slates most remarkable for irregularity. The following are sketches of the curvatures, in Nos. 688, 689, and 690, which are from the Gorge or 'Glen' in Leyden.

Fig. 125.



In Norwich and Enfield this variety has been extensively employed for whetstones: the former locality is far the best, and the latter is now nearly or quite abandoned.

In general this variety occupies the highest place in the mica slate series. Thus we find it on both sides of the valley of the Connecticut, when first we pass on either side of the river from the new red sandstone; and the whole of the mica slate formation in Worcester county is of this description.

This variety is very nearly allied to quartz rock and firestone. Indeed, in respect to extensive tracts, it is often difficult to say whether it should be denominated quartz rock or mica slate. Sometimes it exhibits a jointed structure. It contains also not unfrequently beds or tuberculous masses of white or sometimes blood red quartz.

8. *Firestone.* This most beautiful of all the varieties of mica slate might perhaps with propriety be included under the last variety. For when in its most perfect state to answer the conditions of firestone, the quartz is granular, as in No. 818 from Stafford in Connecticut. But the quartz frequently in Massachusetts becomes hyaline. And it is this circumstance, more than any other, that leads me to fear that it will not make a good firestone. For if the grains of quartz cohere strongly, the stone will be liable to crack. I presume, however, that beds will be found in this rock somewhere along its course, that will be free from this objection. The mica has a silvery whiteness, and frequently exists in almost unbroken laminæ over the surface, so as to give the stone a rich appearance. (Nos. 818, and 2071 to 2073 and 2088.)

9. *Anthracitous Mica Slate.* This is simply a very fine grained mica slate, approximating to clay slate, which has been impregnated and rendered black and shining by carbon. I am disposed to regard the rock constituting the immediate roof and floor of the anthracite bed in Worcester, as belonging to this variety, although I am aware that it has been generally regarded as argillaceous slate. But I think that in all cases careful examination will detect the mica. Of this, however, more in another place. This variety occurs, also, in Auburn and in Dudley, and especially near limestone in Berkshire. (Nos. 717 to 719.)

10. *Plumbaginous Mica Slate.* This rock differs from the last only in exhibiting the gray aspect of plumbago, rather than the dark color of anthracite. But probably in most cases very little plumbago is present. Yet the resemblance is often striking. This variety occurs frequently among the newer beds of mica slate; as for instance on the east side of Connecticut river in Southampton, Conway, Shelburne, &c (Nos. 713 to 715 and 718 and 719.)

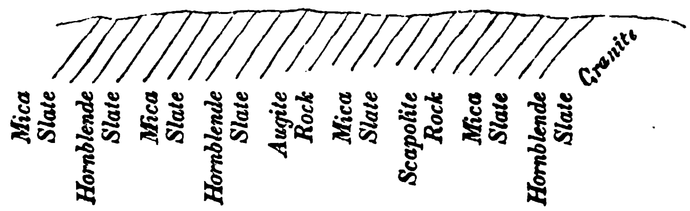
11. *Conglomerated Mica Slate.* In Haverhill and Amesbury I observed fragments of mica slate cemented by the hydrate of iron, so as to form a conglomerate. (No. 716.) It is, however, of very limited extent; occupying only occasional fissures in the rock, and is probably the result of slow disintegration, and the subsequent infiltration of iron from the decomposition of pyrites.

In the vicinity of the sienite in Whately, I found a bowlder obviously composed of fragments of mica slate, which were once partially fused. They are cemented together chiefly by feldspar. The numerous nodules of the mica slate imbedded in the sienite at that place will render this explanation rational, as I shall attempt to show in describing sienite. (No. 724.)

12. *Augite Rock.* It may not be expected to see this rock placed in this connection: since the rock of this name described by Dr. Macculloch in Europe, is an unstratified overlying rock, associated with basalt and greenstone. But the one here introduced, is of entirely a different character. It is ordinarily composed of granular and semi-crystalised augite, of a greenish or yellowish color, mixed with quartz in small quantity; and is interstratified with mica slate and hornblende slate. And since it occurs in too small a quantity to be described as a distinct rock, I thought the proper course would be to notice it in this connection. (Nos. 726, 727.) I have found it only in Williamsburgh, two miles west of the meeting house, at the locality of smoky quartz and plumose mica; where its characters correspond with those mentioned above. But Dr. Emmons informs me that it exists in Chester in the situation exhibited below: that is, there exists in that town such an alternation of strata. One of the beds of this rock is partly made up of 'a variety of *paratomous augite-spar*, which cleaves into thin plates and approaches nearly

in some specimens to schiller spar.' 'Yet,' says Dr. E. 'I should not call the stratum Diallage Rock.' (so it had been called.) 'The loose bowlders which I first found were aggregates of this variety of pyroxene and feldspar. I afterwards found that they came from the mica slate and did not generally resemble granite.' Concerning the scapolite rock, placed by Dr. Emmons on the following section, he has given me no information.

Fig. 126.




## *Topography of Mica Slate.*

It will be seen by the Map that this rock occupies several large tracts in the State. And it exists, also, in small quantities, associated in numerous places with gneiss and granite, but not shown on the Map. Thus the region in Northampton, Williamsburgh, Goshen, &c, colored as granite, is in fact nearly half mica slate. But it would be impossible to represent the true relative position of the two rocks on so small a map; and, therefore, I have colored the whole space as composed of the predominant rock. The same is the case with the limestone district of Berkshire county, where often half the surface is mica slate.

The mica slate of Berkshire varies from that variety, which exhibits the mica in highly glistining distinct scales, to that which is dull and seems to be passing into clay slate, or by taking more or less talc into its compositon becomes talcose slate. A great deal of what I have colored on the map as talcose slate, would by some geologists be regarded as mica slate, because the talc is the least ingredient in quantity. But, wherever this mineral preceptibly modifies the rock, I have regarded the mass as talcose or talco-micaceous rock, and have not described a variety of mica slate as composed of mica quartz and talc. I have regarded Saddle Mountain as ccmposed of talcose slate, although much of the rock might be taken for mica slate. The same thing is true, though in a less degree, of the slate of the Taconic range, especially in its southern part. In Mount Washington, for instance, we sometimes find distinct alternations of mica and talco-micaceous slate. This is the case in Mount Everett especially, (Nos. 2097, 2098,) as it is in Saddle Mountain (No. 2082, 2083, 2100.) Perhaps the mountain west of Lenox contains the largest amount of distinct mica slate of any mountain in the country. (Nos. 2064, 2075.) Where it is interstratified with the limestone, it frequently becomes obscure in its characters and of a carbonaceous aspect. (Nos. 2076, 2082, 2096.) Some might even denominate it in this case clay slate. But it seems to me too distinctly micaceous. In other places, as in Williamstown, (No. 2093,) it approaches still nearer to clay slate. Yet with a glass especially, the small scales of mica are too distinctly obvious to allow me to consider it any thing more than argillo-micaceous slate: and even in Egremont, where I have represented the clay slate on the Map, I am by no means sure that I ought not rather to reckon the rock as simply argillo-micaceous slate. I am probably more inclined than most geologists to limit clay slate to indurated clay, and hardly to regard any specimen deserving this name, in which I can discover scales of mica.

As we ascend Hoosac mountain, the mica slate assumes a much more crystaline aspect and appears to belong to the oldest varieties of this rock. It is essentially of the same character across the whole mountainous range between the valleys of Berkshire and the Connecticut: though as we approach the latter valley, we find it sometimes assuming an argillaceous or arenaceous character; and in Leyden it passes into distinct argillaceous slate.

It will be seen by the Map, that the Hoosac mountain range, (by which I mean all the mountainous region between the valleys of Berkshire and the Connecticut,) is composed mainly of two wedged shaped patches; the one of gneiss and the other of mica slate; the first having its acute angle towards the north, the other towards the south. And yet, according to the Map, which shows the direction of the strata, (Plate 53,) the strata extend uninterruptedly across both the wedges: except for some distance along Westfield river in Chester and Russell, where the strike corresponds nearly with that of the stream. It is a question of no little interest, whether the same strata, which in the south part of the State are gneiss, prolonged into the northern part, become mica slate, and vice versa. That this is possible I admit: and for a case of the sort, I refer to Dr. Macculloch's *Western Islands*, *Vol.* 1. *p.* 307. But in the present instance I am rather inclined to believe that the two rocks do not pass laterally into each other, although I did formerly adopt this view. The strike of the strata just alluded to in Russell and Chester along the river, tends to confirm my present impressions: as this renders it probable that careful examination in that region may show, that the gneiss and mica and talcose slates are arranged in conformable juxtaposition. I have given only the predominant strike and dip of the strata, nor have I found time to make those careful explorations on foot, which are necessary to settle this question. I feel exceedingly undecided on the point. For much of the gneiss in the southern part of the State is verging strongly towards mica slate. And then, I find that as we go northwards into Vermont, a range of gneiss commences, as shown upon the Map, in connection with the Whitingham limestone; and it becomes of considerable breadth farther north. It is not impossible but that a range of gneiss extends uninterruptedly across Massachusetts, but covered in some parts by mica slate. Were it not that the strata along the ridge where this gneiss must run, stand nearly perpendicular, I should be more disposed to adopt this view: but perhaps this is not fatal to it.

Near the central part of the Hoosac mountain range of mica slate, occurs a range of talcose and chlorite slates, in conformable order, and passing insensibly into the mica slate. Hornblende slate and limestone are connected with it still more intimately, as the Map will show.

The narrow range of mica slate on the Map in Northfield, shows itself as we ascend the mountainous country east of that village, which is underlaid by a conglomerate of the new red sandstone formation. Soon this mica slate is succeeded by a deposit of gneiss, which extends nearly to Warwick. Here we find alternating strata of mica slate and hornblende slate, till we get into Orange. How far south this mica slate extends, I do not feel sure: but presume it to be succeeded by gneiss south of Miller's river, except a narrow deposit of arenaceous mica slate, embracing the firestone, which I have marked as extending as far south as the Rail Road in Monson; because I have found it of similar characters and running nearly north and south, in the north east part of Wendell, in Shutesbury, in Enfield, in Palmer, and on the Rail Road in Monson. I have little doubt from its characters, but it extends into Stafford, and connects with the firestone quarry in that town. It may not, indeed, be possible to trace it every rod of this distance, on account of the diluvial coat that covers it. But when I find it at such intervals as above mentioned, and with very similar characters, I feel justified in connecting the different points, at least north of Monson. The rock of this deposit appears mostly to belong to the newest varieties of mica slate; corresponding, in fact, as mentioned in another place, to the metamorphic mica slate of Bellingham and Smithfield. Its dip being usually easterly, leads to the suspicion that between this range of slate and Connecticut river, there may be an anticlinal axis;

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but the strike and dip of the gneiss in that region do not correspond to that idea, till we get as far north as Pelham. If, therefore, such an axis exist in the northern part of the State, I think it *dies out* before we get across the State.

In passing eastward we next come to the Worcester range of mica slate, which has been several times referred to. This rock has often been regarded, either as graywacke slate, or talcose slate, or both. (*See Eaton's Canal Rocks and Geological Text Book.*) But after a careful examination of this formation in various places, from the mouth of the Merrimack to Connecticut line, I am constrained to regard it as one of the latest varieties of mica slate: probably what Humboldt would call transition mica slate. True, I have occasionally met with a limited portion of this rock, which had somewhat of a mechanical aspect; though not much more so than I have found in every range of mica slate which I have examined. In some cases too, there exists a glazing, apparently talcose, on the laminæ of the rock; and this variety certainly approximates closely to graywacke slate. Still, these are not the predominant characters of the formation. Generally the rock is composed of gray arenaceous quartz, and mica in minute scales: the rock exhibiting too much of a crystaline structure for graywacke, and containing moreover, but little if any argillaceous matter. Where it contains considerable oxide of iron, as in the northeast part of Worcester, it presents at a little distance the dirty appearance of sandstone: but a closer examination will show the characters above pointed out. I saw not the least trace, moreover, of any organic remains in this formation; nor have I any evidence that such have ever been found. In short, though very probably genuine cabinet specimens of graywacke slate may be found in this formation, yet as a whole, I could not, without doing violence to my convictions, refer it to any formation, but mica slate. But as I shall place quite a number of specimens from this formation in the hands of the Government, others by inspecting them can form their own opinions as to their nature.

I ought to remark that quartz very frequently predominates in this formation, and the mica almost disappears. Indeed, I am by no means sure that quartz is not the predominant ingredient in the whole formation: and if so, it ought to be denominated quartz rock. And it seems to me that there is much more reason to doubt as to this point, than whether it ought to be referred to graywacke, or talcose slate.

As we approach the east and west sides of this range, the characters of the mica slate become more decided; and in this slate of apparently greater antiquity, the veins and protruding masses of granite are more numerous; though they occur in every part of the formation, and sometimes in the argillaceous slate connected with it. No attempt has been made to give the actual number and extent of these masses of granite on the Map; but simply to indicate where they are most numerous. A large proportion of the most beautiful granite in the State is contained in this formation; and it is entirely wanting in hornblende; which circumstance if I mistake not, affords some presumption of its being among the oldest of the granites.

But does not the occurrence of anthracite in this formation at Worcester, decide at once that it cannot be mica slate? Some might, indeed, doubt whether that mineral is actually contained in the rock under consideration; because the slate forming the immediate roof and floor of the mine so much resembles clay slate But the extent of this slate is quite limited, and then succeeds the rock under consideration; and I have already stated that I regard the slate in which the anthracite lies, as an anthracitous mica slate. I consider, therefore, the anthracite at Worcester as embraced in mica slate.

But can there be any doubt that anthracite does occur in mica slate and even in gneiss? The highest European authorities are, I believe, unanimous on this point. If we consult the *Tableau des Terrains* of Brongniart, we shall see anthracite marked in the stratum of gneiss that lies next to granite; also in his *Phylladique*, a variety of mica slate superior to the oldest variety of the graywacke series, &c. 'It has occurred,' says Dr. Macculloch, 'in gneiss, in micaceous

schist, in primary limestone, and in a conglomerate rock said to belong to the primary rocks.' (*System of Geology*, *Vol.* 2. *p.* 296.) 'It was believed for a long time,' says De Lafosse, 'that anthracite belonged exclusively to the primitive deposits. But it has been since found that it abounds in the secondary and transition formations,' &c. (*Dictionnaire D'Histoire Naturelle*, *Art. Anthracite.*) 'Anthracite,' says Prevost, 'belongs almost exclusively to the oldest of the deposits called transition: where it is met with in beds or veins in the midst of mica slate, of gneiss, and of the *schistes-phyllades*, which overlie vegetable impressions of the family of ferns. For a long time, it is true, it was said that anthracite was found in primitive deposits; but it is probable that this term was applied to rocks and formations which are now placed in the transition formation. It seems almost certain that no primitive anthracite exists.' (*Dict. D'Hist Nat. Art. Houille.*) I asserted in the first part of my Report that some of the anthracite in this country, viz. that at Worcester, occurs in primitive rocks, because it exists in mica slate. When Prevost asserts that 'no primitive anthracite exists,' he means none which he calls primitive. But in the same paragraph he says that this mineral does exist in mica slate and gneiss; every variety of which, geologists of no mean name regard as primitive.

If it be true, as I suppose, that the Worcester anthracite occurs in mica slate, we see the reason why it passes into plumbago, as I have elsewhere shown that it does. For whatever be the cause, as a general fact it is true, that the older the rock in which carbon is found, the more compact it is, and the nearer does it approximate to the semi-crystalized condition of plumbago.

Along the line separating the stratified from the unstratified rocks in the eastern part of the State, extending from the Merrimack river near Newburyport to Franklin, a narrow deposit of mica slate is frequently seen, accompanied by quartz rock: as for instance, the former is found in Sherburne, and the latter in Natick. But the deposits are too small to be represented on a map no larger than Plate 52.

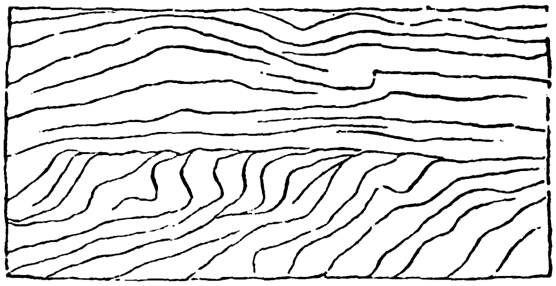
## *Divisional Planes of the Mica Slate, with the Dip, and Strike of the Strata.*

It is rare to find even a small portion of this rock destitute of a schistose structure. But it is not uncommon to meet with extensive masses in which it is very difficult to trace any planes of stratification. In other places, however, no rock exhibits more regularity and beauty of stratification. Such differences may often be explained by local disturbances; but sometimes no appearances will warrant such an explanation of the phenomena. It seems also reasonable to impute something to different proportions of the ingredients in the rock, and to peculiarities in the mode of formation. In general, the less the quantity of mica, the more regular is the stratification. The mica slate in Goshen, Chesterfield, &c., which is remarkably regular in this respect, consists, however, chiefly of mica. Those varieties exhibit most of contortion and undulation in the layers, which are of a plumbaginous aspect, and contain tuberculous masses of quartz.

The laminæ of our mica slate are often a good deal contorted. Not unfrequently in such cases we find planes of stratification running through the rock, which are independent of these curved layers. From the fact, however, that in the curved laminæ we frequently find an alternation of different materials; as for instance, layers of mica slate and quartz, I am inclined to believe that these laminæ were the result of original deposition; although they have been subsequently much contorted. And the planes of stratification too, seem to me to have been produced frequently in the same manner. For in deposits now taking place, we find similar curved laminæ, bounded by similar planes of stratification. Let any one compare the two following figures (127, 128,) with Figs. 61, 62, 63, 70 and 71, which represent diluvial deposits, where similar oblique and curved laminæ are bounded by planes of stratification. In the mica slate, however, it is very probable that some of those divisional planes, which I call planes of stratification, and which are sometimes 8 or 10 feet apart, have resulted from a chemical agency subsequent to deposition.

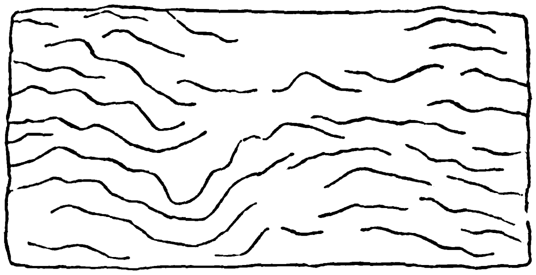
A jointed structure is not unfrequently met with in our mica slate; as may be seen in Nos. 649, 653, 685, 2058; but this rhomboidal structure is usually quite limited in extent.

Fig. 127.



*Contortions in Mica Slate: Whately.*

Fig. 128.



*Contortions in Mica Slate: Conway.*

The following extracts from my travelling notes, will show the dip and direction in numerous places of the strata of the different ranges of mica slate that have been described.

## *Hoosac Mountain Range and that in Berkshire.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Mt. Washington, E. side of Mt. Everett, | N. and S. | E. 90° nearly. |
| do. top of do. | do. | W. 45° to 60.° |
| Sheffield, | N. E. and S. W. nearly. | N. W. |
| Lenox Mt. | N. 10° E. | E. 90° nearly. |
| Lee, N. part. | N. and S. | E. 45.° |
| Williamstown, W. outlet of the Hopper. | do. | E moderate. |
| do. 1-2 mile S. of College. | do. | E. 30° to 40.° |
| New Ashford, Kent's Quarry. | do. | E. 30.° |
| North Adams, near the village. | do. | E. 20° to 45.° |
| do. Foot of Hoosac Mt. | do. | E. 90° nearly. |
| Clarksburg, W. Slope of Hoosac Mt. | do. | E. 20.° |
| Monroe, W. part. | do. | E. 20.° |
| Rowe, in one spot near the center. | E. and W. | S. Small. |
| Rowe to Heath, | N. a little E. and S. a little W. sometimes even 30° or 40.° | E. 90° nearly. |

| | *Strike.* | *Dip.* |
|---|---|---|
| Heath to Colraine. | N. and S. | E. 90° nearly. |
| Shelburne, N. W. part. | N. a few degrees E. &c. | E. 45° to 60.° |
| do. to Deerfield. | N. and S. | E. 60° to 70.° |
| Chester W. part to W. Hampton. | do. | 90° nearly. |
| do. Falley's Cross Roads to Tekoa Mt. in Russell, down Westfield R. | E. and W. | N. 40° to 60.° |
| Tekoa Mt. | N. a little E. | W. 70° to 80.° |
| Southwick, Sodom Mt. E. Side. | N. and S. | W. 60° to 70.° |
| Hoosac Mt. western slope generally, | N. and S. | 20° to 90° East. |
| Florida, east slope of do. | N. a little W. | 70° to 90° East. |
| From Chester to Becket. | N. and S. | 80° to 90° East. |
| Goshen, Plainfield, Hawley, Charlemont, and Zoar. | N. and S. | Nearly 90° East. |
| Goshen, N. W. part of the town. | E. and W. | 25° North. |
| Westfield to Blanford. | N. and S. | 70° to 90° West. |
| Chester, Worthington, E. part. Chesterfield, W. part. Cummington, E. part. | N. and S. | Nearly 90° W. |
| do. W. part. | N. and S. | Nearly 90° E. |
| Colraine. | N. and S. | Nearly 90° E. |
| Whately. | N. several degrees E. | E. 70° to 90° East. |
| Conway, Shelburne, Leyden, Buckland, and Ashfield. | N. and S. | 20° to 70° E. |
| Leyden, at the 'Glen.' | N. and S. | 90.° |

It will be seen that the general direction of the strata in this range is north and south, and the dip very great; for the most part nearly vertical. The most remarkable exception is that which occurs in the northwest part of Goshen, where the strata run almost east and west, and have a comparatively small dip. Although these strata are remarkably regular, yet I cannot but believe that this peculiarity has resulted from the protrusion of that vast mass of granite which lies a little east of the slate in that town, in Williamsburgh, Northampton, Whately, &c.

### *On the Eastern Slope of the Connecticut Valley.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Northfield, E. of village. | N. a few degrees W. | E. large. |
| do. South Mt. | N. and S. nearly. | E. large. |
| do. W. of Ct. River. | do. | E. 20° to 60.° |
| Warwick, S. part. | N. E. and S. W. | N. W. 30° to 40.° |
| do. from center to east line. | S. 20° E. &c. | E. 70.° |
| North Orange. | N. and S. | 90° |
| Enfield, Firestone Hill. | do. | E. 45° to 60.° |
| Wilbraham, (Sodom.) | N. and S. | 90.° |

### *In the Valley of Worcester and the Merrimack.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Haverhill. | N. several degrees E. | Westerly. |
| Boxford. | N. E. and S. W. | N. W. 25° to 60.° |
| Dracut, near Lowell. | do. | 90° nearly. |

| | | |
|---|---|---|
| Lowell. | N. E. and S. W. | 90° nearly. |
| do. to Westford. | E. N. E. and W. S. W. | 90.° |
| Methuen, Spicket Falls. | N. E. and S. W. | N. W. large. |
| Andover, Bridge on Merrimack. | S. 30° W. and N. 30° E. | N. W. 30° to 45.° |
| Groton, 2 miles E. of center. | N. E. and S. W. | N. W. small. |
| Pepperell, 1 mile E. of center. | do. | 30° to 60° S. E. |
| Townsend, near the Harbour. | S. 30° W. | 25° S. E. |
| Westminster, 1-2 mile E. of center. | N. and S. | 20° to 30° E. |
| Auburn, (Ward) center. | N. and S. nearly. | 90° nearly. |
| do. | do. | 70° to 80.° W. usual dip. |
| do. 1-2 mile east on R. Road. | W. S. W. and E. N. E. | 45° N. W. |
| Leicester, 3 miles E. of Clappville. | N. E. and S. W. | 60° to 70° N. W. |
| Webster, E. of Village. | do. | N. W. |
| do. in other places. | N. and S. | W. 45.° |
| Worcester, west of hill of granite. | N. and S. | 25° W. |
| do. East of the same. | Various. | 25° to 90° Easterly. |
| From Worcester to Berlin. | N. E. and S. W. | 20° to 90° N. W.? |
| Sterling. | N. several degrees E. | 60° to 70° W. |
| (This last is the most usual dip of the mica slate.) | | |
| Leominster. | N. several degrees E. | W. large. |
| Fitchburg to Lunenburg. | do. | 10° to 30° E. |
| Between Lunenburg and Shirley. | do. | W. Small. |
| Groton. | N. E. and S. W. | 30° to 45° S. E. |
| Pepperell. | do. | Nearly 90° N. W. |
| Townsend. | N. and S. | 30° to 60° E. |
| Andover. | E. and W. | 70° to 90° N. |
| Methuen to Dracut. | N. E. and S. W. | Northwest, large. |

There would seem from the above statement, to be great irregularity in the direction and dip of the strata of this range. Yet it must be recollected, that I was careful to notice all the important anomalies in these respects, that fell under my observation; while I made few records where the usual dip and direction were observed. Hence the statement above made, in respect to the usual dip and direction may be true, although not taught by the preceding table. And the same remarks are in a measure applicable to other rocks. To prevent any false inferences from such statements, I have drawn the Map, Plate 53, which exhibits the predominant strike; and the sections on Plates 54, and 55, which exhibit the predominant dip, of the strata—anomalies being neglected, unless they are of considerable extent.

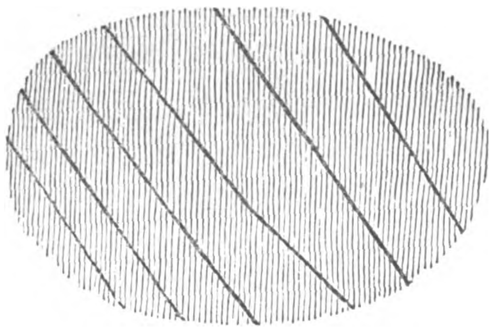
## *Veins in Mica Slate.*

These consist chiefly of granite and quartz; but it will be more convenient to describe them when treating of granite.

Some of the more close grained and imperfectly schistose varieties of mica slate exhibit by disintegration, that kind of structure which has been sometimes denominated *veins of segregation:* that is, veins produced at the time of the formation of the rock, or when it was in a fluid state, by the play of chemical affinities, which in a measure separated the ingredients into different masses; so that when atmospheric agencies wear away the rock, the harder parts remain in relief on the surface, like genuine veins. The following is a sketch of a bowlder of mica slate, not more than two feet in diameter, which exhibits a double set of these segregated ridges, the smaller ones amounting to fifty five, and the larger ones not being parallel to one an-

other. The direction of the slaty laminæ in this bowlder, probably coincides with that of the most numerous ridges.

Fig. 129.



*Veins of Segregation in Mica Slate: Chesterfield.*

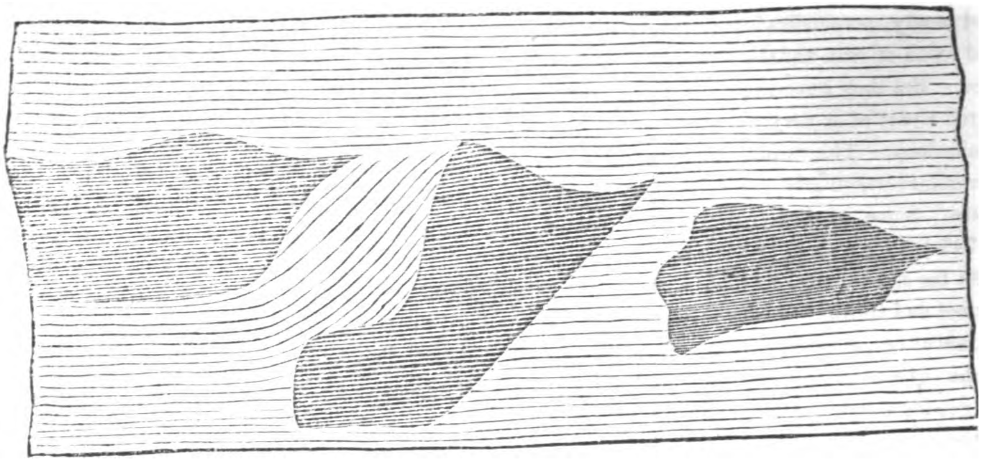
### *Hornblende Aggregate insulated in Mica Slate.*

Near the beds of magnetic oxide of iron in Warwick, I noticed several masses of an aggregate of hornblende, feldspar, and mica, in detached fragments in the mica slate; which appear as if they once formed one continuous mass, but had been broken asunder and subsequently cemented into the slate. The layers of slate between them are somewhat bent. The aggregate is also laminated, though the laminæ do not, as I know of, correspond to the lines drawn upon the fragments on Fig. 128, which were put on by the engraver merely to produce a darker shade. This figure gives but an imperfect idea of the spot. The smallest of the fragments are about 3 1-2 feet long, and the middle one considerably longer. I pretend not to draw many inferences from such a fact as this. But it is difficult to examine the spot and not feel that the mica slate must sometime or other have been so much in a state of fusion as to admit of the fracture and dislocation of the imbedded aggregate. It is singular, however, that such a degree of mobility among the particles, should not have obliterated the marks of a slaty structure which certainly existed previous to the disturbance, because they appear to be laminæ of deposition.

### *Mineral Contents.*

More simple minerals occur in this rock than in any other, with the exception perhaps of granite.

Fig. 130.



To begin with the earthy salts: it is hardly needful to mention one so common as calcareous spar, which always occurs more or less in connection with limestone. It is in distinct crystals sometimes, also, in mica slate; as at Chester, where several of its secondary forms have been noticed. The laminated variety occurs in connection with the micaceous limestone in Whately, Conway, &c.

The sulphate of alumina and potassa, or native alum, is not unfrequently found efflorescing upon mica slate; resulting from the decomposition of the sulphuret of iron and probably also of feldspar, as this is the most probable source from whence it derives the potassa. In Sheffield it is said that 'pounds of it can easily be collected in as nearly a pure state as that of commerce.' (*Robinson's Cat. of American Minerals, p.* 69.) In the northeast part of Conway is a locality, which seems to merit the attention of the manufacturer. (Nos. 2086, 2087.)

The phosphate of lime has been noticed in Williamsburgh, Chesterfield, Chester, Middlefield, Norwich, Hinsdale, &c. That in Williamsburgh is in hexagonal delicately green crystals, and is doubtless apatite. That in Chesterfield is associated with hyanite, as may be seen on No. 750, and almost exactly resembles the chrysoberyl of Haddam; but the ease with which it is impressed by steel, shows its nature at once. In Norwich this mineral occurs in a gray quartz and black mica, and in the vicinity of granite. One of the imperfect crystals which I found, (of which No. 728 is part,) was three inches in diameter, and six inches long.

Fluate of lime exists in small quantity in the mica slate in Conway.

Almost every variety of quartz described in the books, occurs in our mica slate. It is hardly necessary to mention crystalized quartz, which is found almost everywhere, and in nearly every rock. The white hyaline quartz, passing into white milky quartz, exists in large beds, or tuberculous masses, in almost every part of the mica slate. It is an interesting fact, that a large portion of this quartz is fetid in the Hoosac mountain range. I have observed this variety on that range from the south part of Connecticut, to the south part of Vermont, over an interval of more than 100 miles. Sometimes this hyaline quartz—as in Shelburne and Colraine—is tinged of a blood red color, and sometimes of a wine yellow, by iron. As the mica slate approaches to clay slate, the quartz becomes bluish and greasy in its fracture. Sometimes, also, it is pavoine or irised, as in Fitchburg, Leyden, &c. It is found, also, of a rose red color, in Williamsburg, Chesterfield, Blanford, and Chelmsford. I am not certain that at the two latter places mica slate is its gangue, because I found it only in bowlders: yet I have little doubt that

such is the fact. That in Blanford appears to be the finest; and probably if some pains and expense were devoted to getting it out, rich specimens might be procured.

In the mica slate in the southeast part of Conway, a vein of quartz, six or eight feet thick, and nearly perpendicular to the horizon, runs N. 20° east. It is the gangue of two ores, the red oxide of iron and the pyrolusite: which, however, do not occur in it abundantly at the surface. But they have imparted a great variety of colors to nearly the whole gangue; and rendered a part of it very compact. Hence we find there brown and yellow jasper, and sometimes chalcedony. The various colors, black, white, red, yellow, and brown, are often intermixed, sometimes irregularly, forming breccia agates: and rarely in parallel stripes, forming a banded agate. Some of these, if polished, would form I doubt not elegant ornaments. (Nos. 738 to 743.)

At the same place we find a delicate variety of tabular quartz, in which the laminæ are as distinct and thin as the folia of feldspar. Sometimes they are so arranged as to present the appearance of pseudomorphous crystals; and sometimes they so intersect as to form cells. In the cavities of the compact quartz, there sometimes occur minute crystals of quartz, giving the geodes a rich appearance. (Nos. 746, 747.)

About one mile northeast of the College in Amherst, I have found numerous bowlders almost exactly resembling those in Conway just described. Chalcedony and hornstone, however, occur here rather more commonly. Perhaps these masses were brought to that spot from the mica slate which occurs a few miles north, both in Amherst and Leverett. On page 185 I have described a delicate variety of hornstone (No. 2509) found in Pelham, and which I have placed under diluvium, because it has been found only in bowlders. I suspect it to have been originally derived from the same rock as the chalcedony and hornstone found in Amherst. This point, however, is extremely doubtful; and it would not be strange if it should be found that they were all derived from gneiss, where it is placed in the State Collection.

Some of the quartz of these bowlders is yellow and in small crystals. Yellow and irised quartz also occurs in mica slate in Fitchburg. Jasper is found on the banks of Deerfield and Westfield rivers in rolled masses, and probably originated in mica slate.

The gangue of the lead, zinc and copper ores in Hampshire county, is chiefly crystalized and radiated quartz: and these veins sometimes occur in mica slate: but as they generally traverse granite, I shall describe them in treating of that rock.

The best locality of fibrolite that has been discovered in this slate, is in Lancaster, near the village. It is found in a bowlder. The fibrous structure of this mineral is sometimes almost changed into the foliated. The masses are from an inch to three or four inches long, and half an inch broad. It has been met with, also, in some other places in the State.

Under argillaceous slate, I have noticed the occurrence of beautiful amianthus and bucholzite in the slaty rock that embraces the anthracite in Worcester. If my opinion be correct, in referring that rock to mica slate, these minerals should be described in this connection.

The localities of kyanite are numerous. The best is Chesterfield; from whence large quantities have been obtained; some of it finely crystalized and of a rich color. Its colors vary from nearly white, to dark blue. It is not possible at present to obtain specimens as fine as No. 750. It is found also in Blanford, Worthington, Middlefield, Deerfield, &c. The Rhoetizite is found in Blanford and Russell, according to Dr. Emmons.

Of the situation of staurotide in Massachusetts, I have given a general account in describing the staurodiferous mica slate. Chesterfield perhaps, near the locality of green and red tourmalines, is as good a spot for procuring specimens as any one in Massachusetts. But no specimens found in this State equal those from the western part of New Hampshire.

Dr. Emmons states in his Mineralogy, that pinite is found in Chester: though he does not

mention the rock in which it occurs. I mention it here merely because mica slate is the predominant rock in Chester. It is said to occur also with the andalusite in Lancaster.

The most abundant locality of macle and andalusite in Massachusetts is in Lancaster, in clay slate. But the mineral which has been generally called andalusite, is most abundant in Westford, in mica slate. And I am happy to state that numerous specimens can be obtained from thence. It occurs in the stone walls, from a hundred rods to a mile east of the center of the village, and may sometimes be found in distinct prisms, greatly resembling specimens from Germany. It is of a reddish color, and sometimes the masses are two or three inches across. Generally they are accompanied by a fibrous mineral, resembling talc.

Schorl is not common in mica slate. But in Norwich I found a curved specimen of this rock, nearly a foot square, entirely covered with prisms of this mineral, of the size of a goose quill, and generally acuminated. The specimen was weathered so as to leave the schorl in bold relief.

Scapolite is found at Chester, as already mentioned; and Dr. Emmons in his Mineralogy says that it exists 'in veins in mica slate, associated with hornblende, pyroxene, and garnet; but the crystalization is generally confused and indistinct.' It is unnecessary to refer again to other localities of hornblende and pyroxene as connected with mica slate; except to say, that Dr. Emmons mentions 'Middlefield, Chester, Hinsdale, and most of the mountain towns in New England,' as containing sahlite and coccolite.

Garnet is more widely disseminated in mica slate than any other mineral. It differs in size from an almost microscopic grain, to a crystal of two inches in diameter; and its colors are generally reddish, but sometimes black, even approaching very nearly to melanite. In the slate containing the hyanite at Chesterfield, the reddish garnets are very numerous and sometimes quite large. In the amphibolic aggregates, the garnets are usually black. In Plainfield, Dr. Porter has found garnets disseminated in quartz. Garnet and staurotide are usually associated; as at Chesterfield, Middlefield, and Chester. The usual form of the crystal is a rhombic dodecahedron, which is sometimes truncated on its edges

The mica slate formation in Williamsburgh, Middlefield, Chester, Hinsdale, Cummington, Worthington, Plainfield, &c., frequently contains crystals of epidote. Generally they are imbedded in quartz, and frequently associated with hornblende and augite. Zoisite occurs also in Goshen, Hawley, Middlefield, Chester, Hinsdale, Chesterfield, Conway, Windsor, and particularly in Heath and in the north part of Leyden, in large quantities. Indeed, it may be found scattered over nearly every part of the Hoosac mountain range of mica slate; and on the same range as far northward into Vermont as I have examined.

In the stone walls, 50 rods west of the residence of the late Gov. Lincoln in Worcester, several specimens of idocrase were found a few years ago, associated with massive garnet and pyroxene. It was crystalized in right rectangular prisms, truncated on the lateral edges so as to produce eight sided prisms. There can be little doubt that the rock containing this mineral, belonged originally to the mica slate range of Worcester valley. It appears from Beudant's work on mineralogy, that it exists in mica slate in Europe, although generally of volcanic origin. As the Worcester locality is now exhausted, I am indebted to William Lincoln, Esq. for the specimen, No. 765, in the collection. According to Dr. Emmons the same mineral occurs in Chester.

The latter gentlemen has also found stilbite, heulandite, analcime, and chabasie, with hexahedral calcareous spar, on mica slate in the same town. I am not aware that these minerals (except the last,) have before been found in this rock; although stilbite occurs in the Alps in granite rocks. But the others are confined almost exclusively to trap rocks and metalliferous veins.

Anthophyllite is found in many places in the Hoosac Mountain range of mica slate. It occurs in fibrous masses, or imperfect prisms, imbedded in the mica slate. In Chesterfield it is associated with hyanite and garnets. In Chester it is connected with pyroxene, garnet and staurotide. It is found also in Blanford in abundance.

Cummingtonite is found in Cummington and some of the neighboring towns. I have found it likewise in Warwick, on the east side of Connecticut river. Dr. Thomson is decidedly of opinion that this mineral belongs to a new species allied to the karpholite.

It is not uncommon to find a small quantity of sulphur upon the mica slate in a pulverulent state, and proceeding from the decomposition of some sulphuret. But there is no place where it is found in sufficient quantity to be named.

The anthracite and graphite which I consider as connected with mica slate in Worcester, I have already described. Graphite also occurs in mica slate, west of Connecticut river: as at Cummington, Chester, Worthington, &c. But I know of no interesting localities. The magnetic oxide of iron exists in the same mica slate range, in disseminated octahedra: as in Blanford, Chester, &c. Sulphuret of iron is met with likewise in the same situation. In Heath, some very handsome specimens of cubic crystals have been found. In Hawley, it occurs massive in considerable quantity, near the junction of the mica and talcose slate.

One mile north of the village of Worcester, an excavation was made several years ago in the mica slate in search of silver, &c. as already described in the first part of my Report. It is impossible to ascertain at present how wide is the vein that was explored: but the minerals thrown out, and lying around the opening, are mispickel or arsenical pyrites, carbonate of iron and galena. Sometimes the arsenical iron is in distinct crystals in quartz; but I could not ascertain their form. A little west of the village of Worcester, these same minerals occur in the stone walls, along with the idocrase, rendering it probable that this last mineral originated from that metallic vein.

In Sterling, one and a half mile southeast from the village, are two excavations in the same mica slate as that at Worcester: and large quantities of similar ores have been thrown out. Carbonate of iron is most abundant; arsenical iron less common. Blende, of a cherry red color, is found there in considerable quantity; galena also occurs, which is argentiferous. Sulphuret of iron exists in connection with the ores that have been mentioned, and pyritous copper also, with the carbonate of iron. Before the compound blowpipe the blende was reduced, and burnt with the flame peculiar to zinc, throwing off the white oxide. Numerous quartz veins traverse the carbonate of iron, and a considerable quantity of red oxide of iron occurs in the quartz, probably proceeding from the decomposition of the carbonate. The lamellæ of this carbonate at Sterling, as well as at Worcester, are very much curved and commonly reddish white. These ores at Sterling constitute beds in mica slate, whose strike is several degrees east of north, corresponding to the general direction of the range. The dip at the mines is 60° to 70° west.

The micaceous oxide of iron described in the first part of the Report as in Montague, is in veins traversing mica slate and granite, chiefly the former. But I have nothing to add to the description which I have given of these veins.

Sulphate of iron is not uncommon in small quantities on the mica slate of this State.

The red oxide of titanium or rutile, is very common along the eastern margin of the Hoosac mountain range of mica slate; occurring in four or eight sided prisms, generally striated and often geniculated. It is usual to find it associated with zoisite, as at Leyden, where numerous specimens have been found. Sometimes it penetrates quartz, and sometimes is connected with hornblende. In Shelburne I found it in distinct crystals in the mica slate, without any other mineral. I have found it likewise in Colraine and in Conway. At the latter place I found one or two geniculated prisms, more than an inch thick; also in small crystals having the primary form, that is a right square prism. It is found also in Williamsburgh, Chesterfield, Middlefield, &c. In Chesterfield I found a small quantity of what I take to be the titanite, or ferruginous oxide.

I have already given my reasons for believing that the extensive beds of hydrate of iron in Berkshire county, occur mostly in mica slate. The native iron, which is particularly described in my former Report, occurs in mica slate, in Canaan, Ct. The maguatic oxide is sometimes

found in the same rock, and the sulphuret more frequently. The large beds of the former in Warwick, have been fully described in the first part of my Report. White iron pyrites exists in connection with the Cummingtonite in Cummington: and the magnetic sulphuret is said to be common in the State, though I have not met with it. It has been said, also, that the mineral which forms the spangles of spangled mica slate, may be gigantolite. In Auburn, near the meeting house, I found a mineral, which Dr. C. T. Jackson discovered about the same time in bowlders in Rhode Island, and which he has since denominated *Masonite*, in honor of Mr. Owen Mason of Providence. It is a silicate of alumina, iron, and magnesia. Nos. 2138, 2139, and 2140, will show its appearance at the two localities above named.

### *Theoretical Considerations.*

The most important points of a theoretical kind, which might properly be discussed under mica slate, relate to the metamorphic character of that rock, and the other primary stratified rocks, and to the mode in which the contortions and dislocations of the mica slate have been produced. But these subjects can be better examined in the last part of my Report.

## II. TALCOSE SLATE.

I shall include in this formation the three rocks represented on the Map under the names of talcose slate, chlorite slate, and steatite.

Dr. Macculloch describes talcose slate as differing from mica slate only in the substitution of talc for mica: that is, it consists essentially of quartz and talc. It is this variety that constitutes the principal portion of talcose slate in Massachusetts. But other varieties are found, as the following description will show.

### *Lithological Characters.*

1. *Schistose Talc.* This variety is more or less distinctly foliated and varies in color from blackish green to very light green, or greenish white. (Nos. 789 to 793.) It is the least abundant of any of the varieties.

2. *Steatite.* This is obviously only a scaly and semi-granular or partially indurated variety of talc. 'We see,' says Beudant, 'by these analyses, (which he had just quoted,) that the steatites differ from talc only by the presence of water. These substances also occur together and in the same geological position. They appear even to mix in all proportions, and in some suits of specimens, there seems to be a passage from one substance to the other.' (*Mineralogie, Tome 2, p. 212.*) These remarks correspond exactly with the steatite of Massachusetts; although we have some beds of steatite which are associated with but a small quantity of foliated talc. But in general, these beds constitute a part of the talcose slate formation.

The color of this variety is usually light gray. In some quarries, however, (as in Rowe and Zoar,) it is a delicate green; and in such cases the rock is obviously nothing but foliated talc, which is so compact that it forms a fine stone for economical purposes. In the quarries the green and the gray varieties alternate; although not easily divided; and perfectly sound blocks may be obtained, which are partly gray and partly green. (Nos. 794 to 805.)

3. *Chlorite Slate.* Sometimes this variety is foliated and of a dark green color; and in such cases I know of no means of distinguishing it from talc, except, perhaps by its darker color. Generally it is slaty in this region, and very minutely scaly. In this case it probably owes its slaty structure to a small proportion of quartz which it contains. But the chlorite slate of the Hoosac mountain range is remarkably pure; and I may add, remarkably regular and continuous in its slaty structure. (Nos. 806 to 816.)

4. *Quartz and Talc.* In this variety the talc is usually scaly, and the quartz arenaceous. Sometimes, however, the latter is coarsely granular or hyaline.

5. *Quartz, Talc and Mica.* This variety may be considered either as mica slate, which takes into its composition more or less of talc, or as talcose slate, containing mica. Probably but little of our talcose slate can be found, that does not embrace a small proportion of mica; but talc and mica often resemble each other so exceedingly, that it is very difficult to say whether the rock is talcose or mica slate. I have felt this difficulty most in relation to a considerable part of the slaty rock in Berkshire County. (Nos. 826 to 831.)

The fourth and fifth varieties constitute the greater part of the talcose slate formation in Massachusetts.

6. *Talc and Carbonate of Lime.* Sometimes talcose slate lies next to limestone, as in Whitingham, Vt., and near the junction of the two minerals, they are mixed together. But the variety is hardly worth naming. (No. 832.)

7. *Talc, Quartz, and Carbonate of Iron.* It might be more proper, perhaps, to describe the carbonate of iron as disseminated through the talcose slate; though the iron most commonly occurs in the variety, No. 4. And this mineral, by its decomposition, imparts a character to this rock which will be noticed every where. It abounds in spots of the color of iron rust, and this is particularly the case where masses of quartz exist of considerable size. If I mistake not, it is in this decomposed carbonate of iron, that native gold occurs. (Nos. 833, 834.)

8. *Talc, Quartz, and Hornblende.* The latter mineral is in distinct though imperfect crystals scattered through the rock; but it occurs in such quantity, and over so great an extent of country, that it seems proper to make this a distinct variety. It is found along the eastern margin of the talcose slate formation, near its junction with the mica slate in Hawley and Plainfield; and it sometimes passes into distinct hornblende slate. (Nos. 835 to 839.)

9. *Talc, Feldspar and Quartz.* This variety is intermediate between talcose slate and gneiss; and differs from the latter rock only by the substitution of talc for mica. It is obviously, however, a rock more mechanical in its character than gneiss; the feldspar existing in coarse grains. In Hawley the feldspar is scattered in crystaline masses through the rock, forming a distinct porphyritic talcose slate; (No. 841,) and it is almost destitute of stratification.

## *Topography of the Talcose Slate.*

The oldest deposit of this rock in Massachusetts, is in the midst of the mica slate of the Hoosac mountain range. It occupies a very elevated portion of that range, and is there obviously one of the oldest of the stratified rocks. I have traced this rock 20 or 30 miles into Vermont, where it is associated with limestone and gneiss on the eastern slope of the Green Mountains; and probably it extends much farther north. In Massachusetts it is most perfectly developed in its characters in Hawley and Plainfield; where it is several miles wide. Proceeding southerly this formation becomes narrower, and at length appears to terminate near the southern part of Becket; at least I have not observed it farther south, and between Chester and Becket it is only a few rods wide, alternating with mica slate and hornblende slate. The chlorite slate forms a narrow stratum along the western margin of the talcose slate, and I have not observed it quite as far south as the talcose slate. But northerly I have traced it as far as Whitingham, Vt., al-

though I have not seen it in every place where I have crossed the Hoosac range. But being a remarkably distinct stratum, I have little doubt that it does extend as far, at least, as it is represented on the Map, and that it is continuous; since it is so narrow that it might in many places easily be hidden by diluvium.

Several beds of steatite are connected with this range of talcose slate: viz. one in Marlborough, Vt.; one in Rowe; one in Zoar; one in Windsor; two in Middlefield, and farther south, nearly on the line of the strata prolonged, we find a bed in Chester, in Blanford, and at least two in Granville. The bed in Hinsdale, that in Cheshire, that in Savoy, and two of those in Windsor are in gneiss.

In Zoar, we find mica slate, talcose slate, steatite and serpentine, interstratified. The most easterly bed in Windsor appears to be embraced in chlorite slate. That in Middlefield has talcose slate on the east side and hornblende slate on the west. That in Blanford, one and a half mile southwest of the meeting house, is in mica slate; but on one side a huge vein of granite lies in contact with the steatite.

The principal deposit of talcose slate given on the geological Map, embraces Saddle mountain and the Taconic range, the loftiest mountains in Massachusetts. It is interstratified with the mica slate and limestone, also, in some of the valleys of Berkshire: but chiefly near their western side; except at Adams, where we find the talcose slate at the foot of Hoosac mountain in nearly perpendicular strata. All the talcose slate in the west part of Berkshire, embraces more or less of mica, except perhaps occasional beds of chlorite slate: and often it passes into mica slate so entirely, as to perplex the observer. I suppose that the term *micaceo-talcose slate* would be the most appropriate one for this rock. Although frequently much resembling the talcose slate of the Hoosac range, yet in general it is obviously a newer deposit, passing insensibly on its western side into argillaceous slate. Crystalized minerals are not common in it, except octahedral iron ore, quartz, and a few others: though such minerals are not abundant in the Hoosac mountain range. But a comparison of the specimens from No. 2149 to 2178, with Nos. 819 to 831, will afford a better idea of the characters of these two deposits, than mere description.

The steatite beds marked in Shutesbury, Wendell, Petersham, Fitchburg, Worcester, Millbury, and New Salem, are surrounded by gneiss of the most decided character. That in New Salem contains serpentine, also, of a black color. The bed of serpentine, exhibited in Pelham, is a mixture of serpentine and talc: and is marked as serpentine, only because that mineral predominates. It forms a bed in gneiss. The bed in Groton is in mica slate, and that in Andover, in hornblendic gneiss.

It is hardly necessary to say, that this rock is always schistose in its structure; though in the most compact soapstone, both the slaty and stratified structures are nearly obliterated. Yet in some portions of the bed, they are usually visible. In both these structures this rock corresponds very nearly with mica slate; except that the former is less contorted than the latter. Chlorite slate is particularly remarkable in the Hoosac range, for the evenness and beauty of its layers, comparing in this respect with argillaceous slate.

## *Strike and Dip of the Strata.*

### *Taconic Range.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Boston Corner. | N. a little E. | E. 50° to 60.° |
| Mt. Washington, Alender Mt. | N. and S. | 90.° |
| Tom Ball, Alford. | do. | 90° E. nearly. |
| Taconic Mt. Alford. | do. | do. |
| do. West Stockbridge. | do. | E. large. |

| | *Strike.* | *Dip.* |
|---|---|---|
| West Stockbridge, Hill near Center. | N. and S. | do. |
| Lanesborough, Taconic Mt. | N. 30° E. | 45° S. E. |
| Williamstown, do. | N. and S. | E. 20° to 50° increasing as we go Westerly. |
| do. Talco-argillaceous Slate, 1-2 mile S. W. of College. | do. | E. 20° to 50.° |
| Adams, E. ridge of Saddle Mt. | N. E. and S. W. | N. W. 30.° |
| do. Saddle Mt. average. | N. 30° E. | S. E. 40° to 70.° |
| do. near N. Village. | N. a few degrees E. | 90.° |

## *Hoosac Mountain Range.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Florida, E. slope of Mt. | N. and S. | 70° to 90° E. |
| do. near W. side, top. | do. | 15° to 20° E. |
| Middlefield. | do. | 70° to 80° E. |
| Plainfield, Hawley, Charlemont, Rowe, (generally,) Zoar, Cummington, Chester (W. part,) and Worthington. | do. | Nearly 90° E. |
| Rowe, N. part. | E. and W. | S. small. |
| Windsor, Chlorite Slate. | N. and S. | 70° to 80° E. |
| Peru. do. | do. | 90.° |
| Whitingham, Vt. do. | do. | 90° E. nearly. |
| Somerset, Vt. Iron Mine. | do. | 20° to 90° E. |

## *Mineral Contents.*

This rock in the Hoosac mountain range, must be regarded as a metalliferous deposit. Perhaps the most important metal which it contains is iron. This is found principally in four places, viz. in Somerset, Vt. and in Hawley, Chester, and Blanford, Mass. Smaller masses have been noticed in other places; but not in sufficient quantity to be of interest in an economical point of view. At all these localities, the ore is found in distinct beds in the strata; and sometimes it has a slaty structure, having every appearance of a contemporaneous origin with the rock.

I have already remarked, in the first part of my Report, that the iron ore in Hawley embraces two species; the magnetic oxide, and the micaceous oxide. Both of them are of fine quality. The micaceous oxide, especially, is as beautiful as any which has been found on the globe, as the specimens will show. (No. 844.) This bed does not occur, as is usually stated, at the junction of the talcose and mica slate; but two or three miles within the talcose slate—that is, reckoning from its eastern margin.

The most valuable ore at Somerset is the magnetic oxide. With this, however, is associated, often in the same bed, the hydrate of iron. Several of these beds occur in the vicinity, and sometimes they are connected with dolomite. The magnetic oxide is generally granular, and often easily crumbled into powder, which possesses so much brilliancy, that it has been used as a substitute for smalt. It is so highly magnetic that it strongly attracts the fragments of the ore that have been broken off, and exhibits decided polarity; so as to form very fine specimens of the natural magnet. (No. 845.)

The beds of magnetic oxide of iron in the west part of Chester, which are nearly a foot wide, occur in hornblende slate: but this appears to me to be interstratified with the talcose slate, so that probably the ore should be regarded as a continuation southerly of the beds in Hawley. Still farther south, large masses of this ore have been found in Blanford; but with what rock they are associated, I know not.

In the first part of my Report, I have given a full account of the native gold found in connection with magnetic oxide and hydrate of iron in Somerset, Vermont. The usual gangue of the gold is the hydrate of iron: but whether enough of the metal exists in it to render it an object to separate the gold, has not been determined. Usually quartz exists in connection with the hydrate of iron. This is porous and contains the hydrate, and exactly resembles the gangue in which gold has been found in the Southern States. For comparison, I have placed specimens from Somerset and from Virginia in the collection. (No. 848, 849, 850.)

This porous quartz and the hydrate of iron are very common throughout the talcose slate of Hoosac mountain; and the iron results, if I mistake not, as already mentioned, from the decomposition of the carbonate. Whether the hydrate at Somerset had such an origin, I have no means of ascertaining; but if ever gold should be found at other places in this formation, I predict it will occur in connection with this hydrate of iron.

Quartz and hydrate of iron then, appear to be the immediate matrix of the gold of Somerset; and talcose slate the rock in which the quartz and iron are contained. It is rare that we can at once trace this metal so satisfactorily to its original bed. But so far as can be judged by specimens, we may expect that such will be found to be the situation of the gold in the Southern States. For those specimens contain quartz, hydrate of iron, and talcose slate. (Nos. 848, 849, 850.)

The geological situation of the Vermont gold corresponds remarkably with its situation in other countries; particularly in Brazil. It is described as occurring there, disseminated in a rock, called by Al. Brongniart, *Siderocriste* (*Eisenglimmerscheifer* of Eschwege,) and composed of quartz with the specular and magnetic oxides of iron. (*See Tableu des Terrains, &c. p.* 329: *Classification des Roches, p* 83: *and Dictionnaire D'Histoire Naturelle, Art. Or.*) These are the two species of iron ore that occur at Hawley: and it ought to be recollected, that in the vicinity of the iron mine in that place, quartz predominates so much, that I have described the rock as a variety of quartz rock. It is said, indeed, that siderocriste is connected in Brazil with mica slate. But in the rock at Somerset mica occurs: and I am by no means confident that some geologists would not regard it as mica slate; and besides, the mica and talcose slates are interstratified and otherwise more intimately mixed; so that I am disposed to believe that the formation which I have called talcose slate, in Massachusetts and Vermont, corresponds to that containing gold in Brazil, as nearly as could be expected in countries so remote. And although at Somerset the gold has been found chiefly in the hydrate of iron, yet it probably exists also in the magnetic oxide, and not improbably in the micaceous oxide at Hawley. The ferruginous breccia that covers the siderocriste in Brazil, and probably contains platina and diamonds as well as gold, has not to my knowledge been found in Vermont or Massachusetts; yet it may be found still, as very few researches have been made on this subject.

We ought to guard against the idea that all gold must occur in talcose slate, because we know that some does; and because the happy suggestion of Mr. Eaton on this subject led to the discovery of that at Somerset. For veins of quartz containing this metal traverse other rocks in France, Peru, and Mexico. They occur in granite, gneiss, mica slate, and talcose slate. (*Dictionnaire D'Histoire Naturelle, Art. Or.*) Hence we may find it in all these rocks, which are so intimately associated in Massachusetts and Vermont.

Another interesting ore in the talcose slate of the Hoosac mountain range, is manganese. It exists in beds or interstratified layers in the slate, precisely like the cres of iron above described.

These beds are found in Plainfield, and several of them occur near one another, at two principal places, which are represented on the Map: that is, we find smaller and larger beds within a few feet or rods of one another. These beds are rarely more than three or four feet thick. Their surface is black or dark gray, apparently the common pyrolusite. But on breaking open the mass, we usually find its interior to be of a beautiful rose red. This ore has been recently analyzed by Dr. Thomson, and found to be a bi-silicate of manganese. In the stone walls, a little northeast of the meeting house in Cummington, numerous large blocks of this ore are found, which were probably transported thither from the beds above described, by a diluvial current from the north: though to reach this spot, they must have passed over a deep valley, through which a branch of Westfield river now runs.

Connected with the bowlders of this manganese ore in Cummington, I found small but well characterised masses of carbonate of iron.

In the beds of steatite that have been described, several minerals of interest occur. Foliated bitter spar exists in almost every one of them; especially at Middlefield, Windsor, Zoar, and Marlborough, Vt. At Middlefield it is sometimes three or four inches in diameter, enveloped in masses of delicate green talc; and is either white or of a salmon color, so as to form elegant specimens, as may be seen in the collection. In Zoar and Marlborough, and also in connection with the serpentine in Newport, R. I. the columnar variety, called miascite, occurs. In Marlborough and Newfane, Vt., are found also those insulated rhombohedral crystals, called Rhomb Spar. In the bitter spar of Middlefield, sometimes occur tremolite and hepatic sulphuret of iron. The ligniform and compact varieties of asbestus are found in the same steatite bed. They exist also in Zoar. At the soapstone quarry in the east part of Windsor, has been found a small quantity of chromite of iron of good quality. Sulphuret of molybdenum is said also to have been found in the Middlefield steatite; and the variety of talc called nacrite, occurs half a mile west of the meeting house in that town.

No mineral is more common at these steatite beds than actynolite. It is in bladed crystals, long and slender, yet generally very distinct, being mostly six sided. It is found at Middlefield, Windsor, Zoar, &c. But the finest specimens come from Blanford, Mass., and Newfane, Vt. At the former place it is sometimes in radiated masses.

It has been already stated that imperfect crystals of hornblende are sometimes disseminated in one variety of talcose slate. The finely fibrous hornblende I have also found in quartz belonging to this same rock. But the most remarkable variety of this mineral is the fascicular. The laminæ, sometimes three or four inches long, and generally more or less curved, are disposed perpendicularly to the layers of the slate, so that their edges appear on the surface. When that surface is light colored, as in Nos. 864, 865, the distinctness and regularity of the fascicular and scopiform groups of hornblende are very striking. If this variety deserves a distinct name, none can be more appropriate than *fasciculite*, under which I long ago described it in the American Journal of Science.

The chlorite slate abounds, throughout its whole extent, with distinct crystals of octahedral iron ore. They exist also in the common talcose slate, but not so frequently. The chlorite slate in Windsor, also, near the most eastern soapstone quarry, contains numerous crystals of rutile, imbedded in the feldspar, or rather in graphic granite, which frequently occupies the seams of the slate, or forms small irregular masses in it. But although the specimens are fine, it is with extreme difficulty that they can be obtained. It is a fact worthy of notice, that this rock in Scotland, where it is traversed by quartz veins, abounds in titanite; showing a very great similarity in the causes by which it was produced in distant countries.

Near the locality of chromite of iron in the west part of Chester, a mineral occurs in the talcose slate, (No. 2180,) in distinct prisms of a black colour, which I shall call hornblende. But I

should not be surprised, if a more careful examination than I have found time to make, should prove it to be *acmite*, which comes to us from Norway only.

### *Theoretical Considerations.*

The general theory of the origin of talcose slate, like that of mica slate, will be better understood in the last part of my Report. There is, however, one variety of talcose slate, which occurs half a mile west of the meeting house in Hawley, and affords an evidence not found in our mica slate, of the action of heat sufficient to produce partial fusion. I refer to the porphyritic variety, which I do not find described in European works. It seems to me that every thing which we know of the chemistry of crystalization, forbids the supposition that the porphyritic structure can ever result from any other than an igneous agency. For in what laboratory have distinct crystals been produced in the midst of a mass essentially uncrystalized, except from heat? But it is well known that the porphyritic structure is not unfrequently met with in rocks whose volcanic origin is certain; even in the products of existing volcanos.

In the present instance the almost entire absence of stratification and a slaty structure in the rock referred to in Hawley, gives additional probability to the idea of its having been once in a state of partial fusion.

### 12. SERPENTINE.

Perhaps there is no rock whose origin and geological relations are so unsettled as serpentine. Its external characters are not, indeed, obscure; and analysts have given, with accuracy, its ultimate elements. But is it an altered or unaltered rock? If altered, what was the original rock? Is it stratified, or unstratified? primitive, or transition? These are questions on which geologists are not yet agreed. The Dictionnaire Classique D'Histoire Naturelle, says, that serpentine is 'principally situated in the latest of the primitive rocks and in the intermediate class.' Brongniart doubts whether it is found so low as the primary rocks; (*terrains agalysiens*;) and he says that 'no rock of this group, (*Ter. Plut. Ophiolithique,*) exhibits even a tendency to stratification.' (*Tableu des Terrains, &c. p.* 350.) De La Beche classes it with the unstratified rocks. (*Geological Manual, Second Edition, p.* 487.) But Dr. Macculloch considers it as sometimes stratified and sometimes unstratified; and accordingly enumerates it in both these classes; (*System of Geology, Vol.* 2, *p.* 197.) and also as a venous rock. He says, also, that it occurs in connection with granite, gneiss, micaceous, chloritic, and argillaceous schists. His account of this rock corresponds most nearly with its

characters in Massachusetts; and here if I mistake not, it is almost always stratified. At least, the exceptions are less important than in the case of limestone; and since I have placed all our limestones in the stratified class, I shall do the same with our serpentines. In almost all cases, also, our serpentines are connected with the oldest rocks; such as gneiss, mica slate, and talcose slate: and if we have any rocks that are primitive, serpentine is one of the number.

## *Lithological Characters.*

1. *Compact Serpentine.* This embraces two mineralogical varieties, the common opaque serpentine, and the translucent, delicate green, noble serpentine. They are of various degrees of hardness, and their fracture is sometimes splintery, sometimes granular, and sometimes foliated splintery. The colors and their intermixture are very various. (Nos. 870 to 885.)

2. *Serpentine and Talc.* The talc is either foliated or in the condition of steatite. Often it is very obvious that the specimen is in an intermediate state between serpentine and steatite. Indeed, all the gradations between the two rocks may sometimes be seen, particularly in the beds of serpentine and steatite embraced in gneiss, in Pelham, Shutesbury, and New Salem. The color of the rock in these cases is quite black. (Nos. 886 to 893.)

3. *Serpentine, Talc, and Schiller Spar.* In this variety, also, the serpentine, as well as the schiller spar, are almost black; while the talc is green, and sometimes quite brittle. This variety occurs only in Blanford, Russell, and Westfield, so far as I have observed. (Nos. 894, 895.)

4. *Serpentine and Carbonate of Lime.* The latter mineral in this variety is white, and the former green, or black. The proportions in which they are mixed is very various. The limestone is sometimes saccharoidal, and thus this rock forms the *Ophicalce Grenue* of Brongniart, who refers to Newbury as one of its localities. (Nos. 896 to 899.) In other cases as in Middlefield and Becket the limestone is compact. (Nos. 1954, 1955.)

Other minerals found in serpentine sometimes essentially modify its characters: such as actynolite, asbestus, massive garnet, compact feldspar, &c.: but such varieties are hardly worth noticing in this connection.

## *Topography, Stratification, and Associated Rocks.*

Since I have so particularly described the localities of our serpentine in the first part of my Report, it may be practicable, without confusion, to bring together all that I know of its stratification and associations, in a topographical order.

It will be seen, by the Map, that the most numerous and important beds of this rock occur near the central parts of the Hoosac mountain range, and especially in connection with, or in the vicinity of, the talcose slate. In Windsor are two beds. The most easterly bed is only a few rods from a bed of steatite; the latter rock appears in the hill forming the south bank of a branch of Westfield river, and the former in the opposite bank. Both the beds are obviously interstratified with chlorite slate, not far from the junction of this rock with common talcose slate. Its color is a pleasant rather deep green; its structure between granular and splintery; and it contains small disseminated fragments of chromite of iron. It is distinctly stratified; the strata running north and south, and standing nearly perpendicular; which is the usual dip of the rocks in the vicinity; though the chlorite slate, a few rods east of the serpentine, dips east about 70° or 80°. Not only is this serpentine stratified, but I observed here, as well as in the same rock in the west

part of Chester, a structure which might properly be called schistose; especially where the rock had been weathered. The slaty laminæ, however, are rather thick and irregular, nor do they extend through the whole bed.

The other serpentine locality in Windsor, is in the northwest part of the town, on land of Samuel Chapman. It occurs at the surface only in large bowlders; though I cannot doubt but it exists in place beneath the diluvium. The rock surrounding it is gneiss alternating with mica slate. The serpentine resembles that in Zoar, and like that passes into steatite so insensibly, that the eye cannot distinguish between the two minerals; and specimens may be found in every intermediate degree of hardness. But the serpentine greatly predominates.

The situation of the serpentine in Zoar, is similar to that of the first bed in Windsor, just described. It occurs on the north side of Deerfield river; and the edges of the strata are here laid bare. They consist of talcose and mica slate, with green and white steatite interstratified, the strata being not far from perpendicular. As nearly as I could ascertain, there are several beds of the serpentine at this place: though the numerous fragments of the rocks that are broken and mixed along these cliffs, render it difficult to determine all the alternations. It may be of consequence to remark, that in one instance at least, I noticed the serpentine lying next to the steatite. The serpentine at this locality is the common variety, and uniform in its color; but of a lively green. In some instances there is a mixture of the serpentine with the steatite.

In Cheshire, a little east of the Four Corners, is a bed of hard serpentine in gneiss: though the extent of the bed it is difficult to ascertain, on account of the accumulation of detritus.

The most northern bed of serpentine in Middlefield is connected with the most northern bed of steatite in that place already described. The bed in the south part of the town is the largest in Massachusetts; being from four to six miles long, and perhaps 80 or 100 rods wide. It extends into the west part of Chester, where it appears on the east side of Westfield river, rising to the height of 300 to 400 feet; and is succeeded on the east by talcose slate, which rises still higher. I examined this rock in the south part of Middlefield, and found it distinctly stratified; the strata running a little east of north, and dipping easterly, from 70° to 80°; corresponding, in these respects, with the adjoining strata. On the west this bed is succeeded by distinct hornblende slate, both in Middlefield and Chester. In the latter place the serpentine is somewhat stratified and exhibits also a slaty structure. The dip, corresponding with that of the talcose slate on the east, and the hornblende slate on the west, is nearly perpendicular; and the direction rather more east of north than in Middlefield. Forming the east bank of the river, the ledges of this rock seem to have suffered much from abrading agents; and the surface is much broken to pieces and the sides very steep.

I observed the Flora of this serpentine ledge to be rather peculiar. It abounds with the sassafras and Prunus borealis; the former of which, especially, is scattered rather sparsely over the neighboring hills. Polygala paucifolia, Saxifraga pennsylvanica, and Convallaria bifolia, I noticed also in great quantities. Ilex canadensis I observed likewise, as well as a rare species of Arenaria. Lichens and mosses, however, are rarely seen upon this serpentine.

Specimens that may be called noble serpentine do occur in Middlefield; but for the most part the rock is the common variety, of a pale green color, and compact structure, abounding, however, in dark spots from the presence of chromite of iron.

Following the direction of the strata southerly from Middlefield a few miles into Blanford, we come to the bed of limestone, already described. Little more than a mile north of this limestone, and about five miles northwest of Blanford meeting-house, on the old road to Becket, and on the northeast side of a pond, there exists a bed of serpentine, which shows itself at the surface over a space about 30 rods in diameter, and it rises 30 or 40 feet above the general level. This large bed evidently occupies the same geological position as that in Middlefield; for the hornblende slate, frequently epidotic, lies in immediate contact with it on the west side; and though

no rock in place appears on the other side, yet we have much reason to believe that talcose slate, or talco-micaceous slate, exists there. Not improbably this serpentine is connected without interruption with the Middlefield deposit. This would make the whole bed ten or twelve miles long.

The Blanford bed is for the most part as distinctly stratified perhaps as that at Middlefield; and its tendency to a slaty structure I think more distinct. The dip and direction of the strata seem to correspond to those of the hornblende slate in immediate contact, viz. the direction north and south, and the dip east, 60° to 70°.

Nearly between the Blanford and Middlefield beds, another occurs in connection with a bed of steatite, in the west part of Chester. Hornblende slate bounds these beds on the west side, and talcose slate on the east side.

Four or five miles south of the bed of serpentine in Blanford above described, is another, not more than 40 or 50 rods east of a soapstone quarry one and a half miles southwest of the center of the town. This serpentine is in mica slate, which dips easterly; and it is distinctly stratified. There is nothing striking in its appearance. The width of the bed is several rods.

I have reason to suppose that another bed of serpentine exists in the eastern part of Blanford, though I have found only bowlders. But the specimens are of so peculiar a character, that I cannot refer them to any known bed. They consist of green serpentine, talc, and schiller spar. (No. 892.)

The serpentine forming the delicate *vert antique* at Middlefield and Becket on the Western Rail Road, (Nos. 1953, 1954, 1955,) ought perhaps to be regarded as intermediate between limestone and serpentine: or rather, as the former converted into the latter; and, therefore, I have placed the specimens among the limestones. Certainly there is no line of demarcation between the substances. I need not repeat that this bed of limestone is in gneiss. In excavating the rail road on the south side of the river in Becket, large blocks of the above description have been thrown out.

The serpentine bed in Westfield is in mica slate, whose layers lean only a few degrees to the west. I speak here of the most southerly point of its appearance. Here it is about four rods wide. It occurs near the junction of the new red sandstone and the mica slate. This mica slate contains numerous veins and protruding masses of granite; and one mass of this rock lies within three or four feet of the serpentine, if it does not actually touch it. The serpentine is distinctly stratified; the dip and direction of the strata conforming to those of the mica slate. Its predominant color is black; but it contains a mixture of indurated greenish talc, and an amphibolic mineral of a gray color. (No. 893.) A considerable part of the rock, however, contains granular carbonate of lime: or rather in some parts of the bed this mineral predominates, and the serpentine is disseminated through it in small pieces. (No. 899.)

Nearly half a mile north of this spot, serpentine again appears on the north bank of Westfield river in Russell; and I have strong reasons for believing it to be a continuation of the bed in Westfield just described. The rock in Russell is a mixture of black serpentine with green, the latter being sometimes very compact and traversed by veins of indurated talc or Deweylite. (No. 885.)

I can hardly doubt but many more beds of serpentine might easily be discovered in the Hoosac mountain range, if ever it shall be an object to make such discoveries. I make this inference from the fact that I have found some of those above described, under circumstances the most unfavorable.

On the east side of Connecticut river but few beds of serpentine have been found in Massachusetts. That marked in Pelham occurs in the southwest part of the town, and exhibits itself over an area of only a few square rods. One may doubt whether this rock should be called ser-

pentine, or steatite: for these two minerals enter into its composition. In general, however, the former, which is of a black color, predominates. It also contains a considerable quantity of asbestus. This bed lies in gneiss; although the actual contact is hidden by the soil. But at a little distance on both sides this rock appears, and no other rock occurs in the vicinity.

The steatite marked as occurring in Shutesbury appears to be passing in some parts into black serpentine; as may be seen from the specimen, No. 805. At the steatite bed in New Salem this change is still more decided, so that large blocks of what must be called black serpentine are found there. (No. 890.)

In giving an account of the limestone found at Newbury, I have mentioned nearly every important circumstance respecting the serpentine of the same spot. It occurs there in veins or irregular masses of only a few inches in diameter. It will be seen by the polished specimens that several varieties at this locality are very beautiful; but they are so intersected by various minerals that only small pieces can be obtained.

At one of the limestone quarries in Littleton, I observed that small masses of green serpentine were disseminated in the rock. (No. 489.) At Bolton, also, according to Dr. Jackson, it occurs in considerable quantity.

I can hardly add any thing to the description which I have given on page 159, of the extensive deposit of serpentine in Lynnfield. It occurs along the eastern border of the gneiss formation, which not improbably may here pass into talcose or hornblende slate.

## *Mineral Contents.*

Serpentine bears a strong analogy to steatite in its mineral contents, as well as in several other respects. Nearly all the simple minerals that have been described as existing in our steatite, occur also in the serpentine. The beautiful green amianthus of Newbury has already been mentioned, and the asbestus of Pelham. At Westfield well characterised actynolite occurs; and also a mineral which I am disposed to refer to anthophyllite. (No. 911.) Here is likewise found a mineral, occupying a vein nearly a foot in width, which is either petalite or scapolite. (No. 901.) It needs farther and more accurate examination. At the same place, as well as in the serpentine at Newbury, we find massive garnet. In Russell, in a supposed continuation of the Westfield serpentine, are found veins of amianthus traversing the rock. In the same rock, and in the Middlefield serpentine, as well as that of Newbury, is a variety of serpentine which has been denominated Deweylite, in honor of Prof. Dewey. Chalcedony is also found in the Middlefield serpentine; and it sometimes passes into hornstone. Large rolled masses of these minerals, sometimes weighing 200 pounds or more, often agatized have been found in Middlefield and Chester, which probably proceeded from some serpentine locality. Dr. Emmons says, that steatite is crystalized distinctly in the serpentine at Middlefield; and he does not regard these crystals as pseudo-morphous; although they correspond in form exactly to those of quartz. In the serpentine of that place drusy quartz occurs, which is extremely beautiful. The dark green schiller spar found in the serpentine of Blanford, Westfield, and Russell, has been already mentioned. It occurs in foliated masses. But the most important mineral in the serpentine of Massachusetts is the Chromite of Iron, whose analysis has been given in the first part of my Report. It exists disseminated more or less in minute grains, through nearly all the serpentine of the Hoosac range. But it has been met with in quantity at only two localities. In the serpentine in the northwest part of Blanford, it exists in tuberculous masses, rarely as much as a foot in diameter. A more prolific locality is in the serpentine in the west part of Chester, near the rail road. So far as I can ascertain, it does not there form a vein, but only an irregular mass; how extensive I cannot say. It is situated perhaps 300 feet above where the rail road is excavated through the serpentine, and on the same side of the river. The serpentine of Lynnfield frequently contains an incrustation of the carbonate of magnesia. (Nos. 2183.)

### *Theoretical Considerations.*

The preceding description will show that the serpentine of Massachusetts corresponds essentially, as to position and character, with those serpentines in Europe that are connected with the oldest rocks. But I am not aware that any statements which I have made, will throw additional light on the obscure subject of its origin. From the statement of Dr. Macculloch (*Edinburgh Journal of Science, Vol.* 1. *p.* 1.) and De La Beche, (*Manual of Geology, p.* 497 ; 2*d Edition,*) as to the connection between serpentine, trap, and limestone, one would be led to infer that the first mentioned rock might have resulted from a mixture of the trap and limestone. But only a part of the serpentines of Massachusetts could have thus originated. The Newbury serpentine, a part of that at Westfield, and that in Middlefield, are associated with limestone, and may have resulted from some metamorphosis of that rock. Indeed, the character of that in Middlefield and Becket is very favorable to such a view. But in general our serpentines are entirely separated from limestone; and in respect to the gneiss east of Connecticut river, containing one or two of these beds, the whole extensive range does not to my knowledge embrace a single bed of limestone. But in nearly all cases our serpentines are associated with talc, either pure and foliated, or as steatite, or chlorite slate, or talc and quartz. The two minerals, (talc and serpentine,) are intimately blended together and pass into one another by insensible gradations. And in all the cases described by the writers above referred to, talc was present. Is it not natural then to suspect that serpentine is talc, or talc serpentine, chemically altered by heat? And since the talc is schistose and the serpentine compact, the latter must have been produced from the former. In some cases it is easy to imagine that the heat might have been powerful enough to produce perfectly fused, and of course compact serpentine, protruding among other rocks in the form of veins; while at other times the fusion was only partial, not sufficient to destroy entirely the stratification. The great similarity in the chemical composition of serpentine and talc also favors the idea that they had a common origin. Both are composed essentially of silex and magnesia, with a considerable proportion of water. But I make these observations with little expectation that they will stand the test of observation. It may be found that serpentine has been produced from various rocks, which contained the necessary ingredients. But that heat has been employed in its production, cannot, it seems to me, be reasonably doubted; not that it is a *metamorphic* rock. And these facts explain at once all the diversities of opinion, respecting its stratification and relative age which we find among geologists.

## 13. HORNBLENDE SLATE.

I use this name as a substitute for Dr. Macculloch's *Hornblende Schist;* and I include under it the same varieties of rocks. These varieties are such as other geologists have described under the names of hornblende rock, hornblende schist, and greenstone slate; all of which, I believe, occur in Massachusetts. In reading Dr. Macculloch's masterly description of the primary rocks of Scotland, I can hardly conceive that he is not describing those of New England; so perfect is the correspondence. Hence I have followed that geologist in describing most of the primary rocks; though I reject some of his distinctions.

All the varieties of rocks mentioned above, viz. hornblende rock, hornblende schist, and greenstone slate, occur, I believe, in Massachusetts; and the system which regards them as separate formations, has long rendered their history obscure and perplexing. But by uniting them, as Dr. Macculloch has done, and regarding them as mere varieties of the same formation, very much of this obscurity vanishes.

### *Lithological Characters.*

1. *Of Hornblende alone.* Sometimes this variety is laminar, and sometimes fibrous. When fibrous, it is slaty; when laminar, no slaty structure can be perceived, nor any stratification, even in beds of considerable extent. This is the rock that has been sometimes called *hornblende rock*. (Nos. 914 to 928.)

2. *Hornblende and Feldspar.* Generally the hornblende is crystaline, and the feldspar foliated, or granular; but sometimes both ingredients are compact. In this variety there is usually little appearance of stratification, or of a schistose structure; though this is not generally true of the whole bed. And sometimes, as in Whately, where this rock often assumes a columnar form on a small scale, a schistose structure may still be seen. Sometimes the feldspar in this rock, as in the west part of Northfield, is finely granular, or even assumes a pulverulent appearance; while the hornblende is distinctly crystaline. When the ingredients are both crystaline, the rock furnishes a good example of hornblende slate. This variety is usually interstratified with gneiss and passes insensibly into that rock. (Nos 929 to 951.)

In Whately is a curious variety of hornblende slate, in which the hornblende is light green and the feldspar white and compact. A casual inspection would leave the impression that the rock is sienite. But a little attention shows a very decided slaty structure. The hornblende also predominates. This is the only example I have met with, in which the slaty variety contains compact feldspar without being porphyritic. (No. 947.)

Associated with a large proportion of the hornblende slate in the vicinity of Connecticut river, is a variety that falls under the present division, that is most decidedly, and sometimes very beautifully porphyritic. The feldspar is yellowish white, between foliated and granular, although sometimes retaining the form of the crystal in considerable perfection. The hornblende is subcrystaline, and in the greatest quantity. Sometimes scales of mica are present. The slaty structure may usually be seen in this variety, though less distinct than in most other varieties of

this rock. . There is scarcely a more distinct variety of porphyry in the State than this; and as it admits of being smoothed, and probably polished, it would form undoubtedly an interesting ornamental stone. It is more common to meet with this rock in rolled masses than in beds; and hence I infer that its beds are rather limited. (Nos. 944 to 946.)

I have found a remarkable variety of this porphyritic hornblende slate in Canton and Easton, near the Blue hills, and also in Waltham, in rolled masses. Its peculiarity consists in the feldspar being compact, yet exhibiting the form of the crystal. The feldspar is white and the schistose structure of the rock distinct. (Nos. 948 to 950.) Whence this rock originated I am unable to say; though probably somewhere not far from the outer limits of the gneiss range, which lies west of the greenstone and sienite around Boston. It is quite obvious that this rock must have been so nearly fused as to destroy the foliated structure of the feldspar, yet without essentially impairing its crystaline form.

3. *Hornblende and Quartz.* (Nos. 952 to 957.) In general, this variety probably contains some feldspar also. The hornblende in a crystaline state forms the principal ingredient. The quartz is granular. The rock is slaty; and is sometimes traversed by veins of quartz or granite. It does not form a common variety.

4. *Hornblende, Feldspar, and Mica.* This approaches to gneiss: but I do not call it gneiss when the hornblende predominates. The mica is usually in small quantity, and the feldspar and quartz sometimes traverse the rock in numerous minute veins, which seem to have been frequently cut off and shifted by one another. (Nos. 958 to 963.)

5. *Hornblende and Epidote.* This latter mineral sometimes constitutes so large a proportion of the rock, that I thought it ought to be regarded as a constituent of one of the varieties of hornblende slate. Generally it is granular and disseminated through the rock, giving it a peculiar green tinge: but sometimes it is imperfectly crystalized in cavities, and sometimes in veins. (Nos. 964, 964 1-2, 965.)

6. *Hornblende and Chlorite.* This variety is rather uncommon: but I have met with it in Whately, Shelburne, and perhaps some other places. Sometimes it passes into genuine chlorite slate. (No. 967.)

7. *Actynolite Slate.* This is found in gneiss in Shutesbury; and I know of no other well marked locality. It occurs near the mineral well near the center of the town. The rock is slaty and is composed of fibrous actynolite, foliated feldspar, mica, hornblende, and quartz, arranged somewhat in layers. It is obviously only gneiss which takes into its composition a large proportion of actynolite. In Belchertown I found a loose specimen, in which the actynolite was granular and in large quantity, and the rock was not slaty. (Nos. 968, 969 )

I doubt not that other and still more compound varieties of hornblende slate might be found among our rocks: for this rock passes by imperceptible gradations into almost all those with which it is associated. Under talcose slate, I have noticed, for example, a variety containing hornblende, which might as well have been reckoned in this place. Under mica slate, I have also noticed an amphibolic variety, in which the hornblende sometimes predominates.

## *Topography of Hornblende Slate.*

Every deposit of hornblende slate which I have examined in New England, is associated either with gneiss, talcose slate, mica slate, or quartz rock. The hornblende slate marked upon the eastern border of the principal deposit of gneiss in the eastern part of the State, is usually associated not only with the gneiss into which it passes, but also with more or less of quartz rock and mica slate: which are not exhibited on the Map, because usually occurring on so small a scale. The hornblende rock is frequently in this region (and the same may be said of the rocks associated with it,) almost destitute of a slaty or a stratified structure, and might easily be

mistaken for trap rock. This makes it extremely difficult to fix the boundaries between the stratified and the unstratified rocks. Where the hornblende slate occurs some distance from the unstratified rocks, as at Marlborough, its slaty character is quite perfect. It alternates more or less with the gneiss and passes into that rock by insensible gradations. Hence the space where this rock is marked on the Map, must not be considered as precisely defining its limits; but only as an indication that it abounds in that region.

The deposit marked on the Map as extending from Monson to the north part of the State, is in like manner often interstratified with the gneiss: indeed, the alternations are often so frequent that they occur several times in a hand specimen; as may be seen in Nos. 1031, 1032. Such specimens present us with a beautiful illustration of stratification on a small scale The regularity of the divisional planes in the range under consideration, is generally quite striking.

The deposit of this rock in the west part of Northfield, north part of Gill, and east part of Bernardston, is represented as in contact with mica slate, quartz rock, and new red sandstone: and such I believe to be its associations. The hornblende slate of this region is sometimes slaty; but very frequently it resembles greenstone, exhibiting even sometimes a passage into sienite. In some parts of the bed no marks of stratification, or slaty structure, appear; but they are almost uniformly present in other parts. In one instance, at least, a vein of white fetid quartz, nearly a foot wide, traverses this rock. This spot is on the road from Gill to Bernardston. The quartz near the edges of the vein contains foliated masses of feldspar.

Hornblende slate is frequently found alternating with the mica slate of Franklin County; particularly in Leyden, Colraine, and Heath. I have marked, however, only a single strip of this rock, covering the region where it is most abundant. In the west part of Shelburne, we find this rock, which there appears to be connected with a limited deposit of gneiss.

On the borders of the primary ranges on both sides of the valley of Connecticut river, we meet frequently with narrow deposits of this rock. In passing from the sandstone towards the gneiss, we usually first strike mica slate and then hornblende slate: but sometimes, as in the south part of Wilbraham, the latter appears first. Of course, the hornblende slate marked on the Map, just on the borders of the primary rocks in Hampden County, and east of Connecticut river, (and the same may be said of almost every other deposit of this rock,) may not be found always in the field in precisely the situation which it occupies on the Map.

About one mile north of Whately Meetinghouse, we find a limited deposit of hornblende slate, on the west side of the street, probably succeeding the red sandstone. Passing westerly not more than 100 rods, we cross almost every variety of this rock, that has been named: the common hornblende slate, which predominates: also that containing epidote, which is frequently divided into rhomboidal masses of considerable regularity: then we come to a variety, where the slaty and stratified tendency begins to be lost in the trappose or columnar: next we strike the peculiar variety already described, as containing white compact feldspar: finally succeeds mica slate. In describing sienite I shall refer again to this spot.

The strip of hornblende slate marked along the eastern margin of the gneiss range in the west part of Hampden County, and the east part of Berkshire, is so intermingled with the gneiss on one side, and with the mica slate and talcose slate on the other, that it is no easy matter to fix upon its true position or extent. I have exhibited it in those places where I found it most abundant. But viewing it rather as a variety of gneiss, I do not regard its exact situation or extent on the Map of any great importance. Traces of this same rock may be seen all along the eastern margin of the talcose slate; and in Plainfield and Hawley, it is not uncommon to find examples of pure hornblende slate: though usually the hornblende forms the least abundant ingredient, and ought perhaps to be considered merely as crystalized hornblende disseminated through talcose slate.

Some of the hornblende rock in Granville and Tolland is laminated, and the size of the laminæ

is often gigantic. I apprehend that this hornblende slate in these towns, is connected with the extensive ranges of that rock which one crosses in passing from Lee to Becket. But I am so doubtful about the true situation of this rock along the western part of the gneiss range in Berkshire County, that I have foreborne to represent it on the Map. In the east part of Lee and west part of Becket, it is associated with augitic gneiss: and both these rocks are obviously varieties of gneiss.

## *Strike and Dip of the Strata.*

Though this rock has sometimes a jointed structure, for a short distance, I have not discovered any planes of stratification making an angle with those of cleavage of much extent. But they may yet be found. The dip and strike usually correspond with the gneiss, mica slate, and talcose slate, with which this rock is interstratified. In my view, indeed, it ought to be regarded as one of the varieties of those formations, probably produced during the same geological period.

| | *Strike.* | *Dip.* |
|---|---|---|
| Middlefield. | N. and S. | 70° to 80° East. |
| Becket, E part. | do. | 90°. |
| do. W. part. | do. | E. 70° to 80.° |
| Blanford, N. part. | do. | 90°. |
| do. N. W. part. | do. | E. 60° to 70.° |
| Granville. | do. | 90.° |
| Chester, W. part. | do. | 90° nearly. |
| Rowe, N. part. | E. and W. | S. Small. |
| Shelburne. | N. and S. | E. 45° to 90.° |
| Northfield, W. of Ct. River. | N. 30° E. | S. E. large. |
| do. S. Mt. | N. and S. nearly. | E. large. |
| Bernardston, E. part. | do. | E. 50° to 60.° |
| Warwick, Mt. Grace. | S. 20° E. | E moderate. |
| Orange, from center to W. line. | N. a few degrees E. | E. 70.° |
| S. Orange. | N. and S. nearly. | 90.° |
| South Wilbraham. | N. and S. | E. large. |
| Monson. | do | W. 45° to 90.° |
| Westborough. | N. E. and S. W. | 50° to 70.° N. W. |
| Marlborough. | do. | 80° to 90° N. W. |
| Sherburne, towards Holliston. | N. W. and S. E. | N. E. |
| Wrentham, 2 ms. N. W. of center. | N. E. and S. W. | S. E. |
| Cumberland, R. I. | do. | S. E. 40.° |
| Smithfield, R. I. lime quarries. | S. E. and N. W. | N. E. 30° to 45.° |
| Troy, E. part, near Hick's M. House. | E. and W. | N. large. |

This rock is frequently remarkable for the numerous and complicated contortions which its layers exhibit, often rivalling in this respect, mica slate and gneiss. Not unfrequently these irregularities appear to be increased by the passage of granite veins through the rock, as in Granville.

## *Mineral Contents.*

So far as it has been examined, no rock in the State appears to be so barren of interesting minerals as this. Garnets are perhaps the most common, and generally they are of a blood red color—probably in some cases the pyrope. In Rowe, epidote occurs in this rock in a state of

such purity that it deserves to be mentioned. In Middlefield and Chester, sphene has been observed in it. In its cavities also, not unfrequently, as in Charlemont and Whately, I have noticed tolerably distinct crystals of feldspar. The immediate gangue of the plumbago mine at Sturbridge is hornblende and feldspar; and the former minerals constitute the gangue to a considerable extent at least, of the arsenical cobalt of Chatham, Ct. Rutite I have also found in hornblende in Leyden. I have already described beds of magnetic oxide of iron in this rock in Chester.

### *Theoretical Considerations.*

It is easy to apply to hornblende slate the theory which imputes to the primary rocks an origin partly aqueous and partly igneous. For it is a very fusible rock, and may hence easily be conceived to have been sufficiently heated to enable it to assume the crystaline aspect, which it almost always exhibits. But from what rock did the hornblende slate originate? The researches of Dr. Macculloch appear to have thrown a gleam of light upon this difficult question. 'As far as a single fact can prove such a case,' says he, 'the origin of hornblende schist from clay slate is completely established by the occurrence in Shetland of a mass of the latter substance, alternating with gneiss and approximating to granite. Here those portions which come into contact with the latter, become first, siliceous schist, and ultimately, hornblende schist; so that the very same bed which is an interlamination of gneiss and clay slate in one part, is in another, the usual alternation of gneiss and hornblende schist.' *(System of Geology, Vol.* 1. *p.* 210.) In another place he says, 'it would appear that the fusion of clay slate, whether primary or secondary, is, under various circumstances, capable of generating, either the common trap rocks, or the hornblende schists: nor is it perhaps difficult to explain, by a more gradual cooling, and consequently, a slower crystalization, the particular causes which may have determined the latter rather than the former effect.' *(System of Geology, Vol. II. p.* 171.)

This theory, if admitted, explains satisfactorily the approximation of hornblende schist to unstratified trap rocks. For some portions of the clay slate would very probably be so entirely fused as to obliterate all marks of a stratified and schistose structure: and hence by slow crystalization might result hornblende rock and primitive greenstone.

The remarks that have been made in relation to porphyritic talcose slate, will apply with still more force to that variety of hornblende slate which is porphyritic. For in the latter case this structure is more distinct and perfect than in the former. And the more I reflect upon the subject, the more satisfied I am, that a porphyritic structure must, in all cases, have been the result of the agency of heat.

## 14. GNEISS.

This rock occupies more of the surface in Massachusetts than any other: and in all countries of much extent hitherto examined, it is one of the most extensive of the formations. Quartz, mica, and feldspar, are its common and essential ingredients; though hornblende is so often present, that some writers regard its claims to be considered essential, as equal to those of the other three minerals. It is obvious, therefore, that the mineralogical constitution of this rock is the same as that of granite. The only difference, indeed, consists in the stratified and slaty disposition of the gneiss. This character, however, sometimes becomes very obscure; and then it is almost impossible to distinguish between the two rocks. They might, therefore, be regarded as varieties of one another; differing only in the mode of their production, as in the case of the stratified and unstratified limestones and serpentine. Little advantage, however, would be gained by such an innovation; and granite and gneiss have so long been considered as classical terms in geology, that if possible they ought to be retained; lest that neological spirit, which vain ambition nourishes, should unsettle every principle of the science.

The gneiss of Massachusetts corresponds almost exactly to that described by European geologists, particularly by Dr. Macculloch. Our gneiss, however, does not to my knowledge alternate with clay slate, as it does in Scotland. I am inclined also to believe, that ours exhibits a greater regularity of stratification, producing a fine rock for architectural purposes.

Although in general the characters of gneiss are tolerably distinct, yet an almost infinite variety of specimens may be obtained, slightly differing in the color, arrangement, or proportions, of the ingredients. They may however, be reduced to a few leading varieties.

### *Mineralogical Characters.*

1. *Granitic Gneiss.* (Nos. 972 to 992 and 2226 to 2234.) I suppose this variety to be the granite-gneiss of Humboldt. It certainly approaches very near to granite; and in hand specimens cannot be distinguished from a coarse grained variety of that rock. Even for an extent of several yards, we can sometimes discover no marks of a laminar or stratified structure: but those structures, at least the laminar, usually appear at no great distance, to prevent our regarding the rock as granite. It might, indeed, on a superficial view, be considered as a vein of granite in gneiss. But the masses will be found too irregular for such a supposition; and often they are bounded on all sides by well characterized gneiss. It would explain the mode in which this rock presents itself, to suppose that a slaty rock was once in a state of partial fusion, while some portions of it were perfectly melted, so as to crystalize in the form of a coarse granite; the principal part of the mass cooling before the slaty structure was entirely lost. In travelling several miles I have sometimes been at a loss to decide whether the rock were gneiss or granite, until a very careful examination disclosed a partially obsolete parallelism of the mica. I think, however, that there

is a slight peculiarity of aspect in most of the granitic gneiss of Massachusetts, which would enable me to distinguish it from genuine granite even in hand specimens, which were totally destitute of a parallel disposition of parts. But it is difficult to describe the exact nature of that peculiarity.

2. *Schistose Gneiss.* (Nos. 993 to 1022.) This is probably the most common variety of our gneiss. The structure is foliated like that of mica slate: though sometimes granular with a laminar tendency. Some of the best quarries in the State I regard as belonging to this variety. It passes frequently into mica slate by the disappearance of the feldspar.

3. *Laminar Gneiss.* In this variety the different ingredients occupy distinct layers. When the mica is black, or there is an interlamination of hornblende, the different laminæ are remarkably distinct and regular. In some instances, perhaps, this rock may be regarded as composed of alternating layers of gneiss and mica slate, or hornblende slate. (Nos. 1023 to 1040.)

4. *Porphyritic Gneiss.* The structure of this variety is more or less slaty. But it embraces distinct crystaline masses of foliated feldspar. Most commonly these masses are somewhat ovoid; but in some instances they present the regular forms of the crystals. The color is sometimes white or gray: but a reddish hue predominates. The imbedded masses vary in size from a quarter of an inch in their longest direction, to two inches; and they sometimes constitute the largest portion of the rock. This variety sometimes answers well for architectural purposes. (Nos. 1041 to 1050.)

5. *Amphibolic Gneiss.* I thus denominate that variety which takes a small proportion of hornblende into its composition: not sufficient to form hornblende slate. This mineral is usually disseminated in black foliated masses, from the size of a pin's head to half an inch in diameter, through the rock. It occurs only in the vicinity of hornblende slate. (Nos. 1051 to 1054.)

In the southeast part of Worcester County is a beautiful rock, extensively quarried, which I refer to this variety. One meets with it abundantly in Mendon, Grafton, and the south part of Worcester, in blocks got out for building: but I do not know where are its quarries. The rock appears to be a granitic gneiss, composed almost entirely of quartz and feldspar, through which are disseminated numerous black crystaline masses of hornblende, which have a somewhat parallel arrangement. This parallelism is almost the only mark by which I distinguish this rock from granite. It might with propriety be termed *sienitic gneiss.* (Nos. 983 and 986.)

6. *Epidotic Gneiss.* This variety usually contains hornblende as well as epidote. The latter mineral is very frequently in veins and generally compact. It is sometimes disseminated through the rock, giving it a peculiar green tinge. Were this not a common variety of gneiss, especially in the vicinity of hornblende slate, it would not deserve a distinct description. It is closely allied to the epidotic hornblende slate. (Nos. 1055 to 1061.) When the epidotic gneiss happens to be porphyritic, it forms a beautiful ornamental stone. (No. 1043.)

7. *Augitic Gneiss.* This interesting rock is usually composed of quartz, feldspar, and lively green augite, in coarse grains or partially crystaline masses. Occasionally we see present grains of black hornblende. The augite seems generally to have taken the place of the mica. The augite is disseminated in various proportions through the mass and the slaty structure is quite indistinct. (Nos. 1062 to 1065.)

8. *Anthophyllitic Gneiss.* In the west part of Enfield and in Belchertown, anthopyllite is disseminated through the gneiss in such quantity, that it deserves to be considered an ingredient of the rock, if it be proper thus to consider amphibole, epidote, and augite, in the three preceding varieties. This rock is composed almost entirely of feldspar, quartz, and anthophyllite; mica being rarely present. (Nos. 1066, 1067.)

9. *Arenaceous Gneiss.* I have found this rock only in one well marked locality, viz. at Southbridge, Worcester county; but it seems to me sufficiently peculiar to deserve a distinct notice. It is composed entirely of quartz and feldspar, which, (particularly the latter,) are in a

finely granular state; embracing, however, small but distinct crystals of red garnet. Between the layers of the rock we find a substance which approaches to talc. This rock is quarried and is employed for lining furnaces. (No. 1068.) Perhaps it ought to be described under the next variety.

10. *Talcose Gneiss.* This is composed of feldspar, quartz, and talc; the first ingredient in the largest proportion. Its structure is irregularly schistose: but it has the aspect of a rock formed in part by mechanical agency.

## *Topography of the Gneiss.*

There are in Massachusetts four separate deposits of gneiss: one in the Hoosac mountain range; two in the central parts of the State; and a fourth in the vicinity of New Bedford, in Plymouth and Bristol counties.

### *Hoosac Mountain Range.*

Under mica slate I have already given a general description of the situation of this gneiss. Throughout nearly the whole extent of Litchfield county, in Connecticut, it is most distinctly characterised. As we proceed northerly into Massachusetts, its characters become less decided. The feldspar is less abundant, and the mica more so; and hornblende frequently abounds in it; so that viewed on a small scale, it may often be regarded as mica slate. Along the eastern slope of Hoosac mountain, the rock is sooner succeeded by mica slate than along the western slope. On this latter side, indeed, distinct gneiss continues nearly across the State, as may be seen on the Map; and I am by no means sure but careful research may trace it entirely across the State; so as to connect it with the gneiss that appears in the lower part of Vermont, along the eastern talus of the Green mountains. At any rate, that Vermont gneiss appears distinctly characterised in the southwest part of Whitingham, near the beds of limestone, as shown on the Map; and from thence I have traced it as far north as the Somerset iron mine. Here then we have two wedge-shaped ranges of gneiss, with their acute angles towards each other, while the space between them is occupied by mica slate and talcose slate; and sometimes we find these slates, for a limited space, passing into gneiss.

In passing from Becket to Lee, we cross strata of decided gneiss, till within three or four miles of Lee, when the rock contains a considerable proportion of hornblende, and at length becomes decided hornblende slate. Still nearer to Lee, the hornblende is replaced by green augite, and augitic gneiss hence results. Within two miles of Lee, we meet with limestone; which often contains a mixture of augite; and this mineral, being decomposed at the surface, yet projecting beyond the limestone, the whole rock exhibits a brown very rough and irregular aspect; exceedingly like similar compounds at the lime quarries in Bolton, Boxborough, Littleton, &c.

The limited patch of gneiss marked on the Map, in Buckland and Shelburne, lies chiefly in the ravine through which Deerfield river passes. In its most elevated parts, (as on the western slope of the high land in the west part of Shelburne, and on the opposite side of the river in Buckland, on the stage road between the two bridges over Deerfield river,) this rock is very regular in its stratification: but at the bottom of Deerfield river, at and below Shelburne Falls, it is the granitic gneiss, almost destitute of stratification, and contains hornblende. The feldspar here is in small proportion; and some of the rock might properly be denominated quartz rock.

These facts have led me to inquire, whether the greater regularity of stratification in the higher parts of this deposit, might not proceed from the fact, that the lower parts are nearer to that

igneous power, which has partially fused some portions of the primary rocks, and entirely fused other portions ? Here the upper strata are perfectly regular and continuous : but as we descend, we find the rock approximating nearer and nearer to unstratified granite, yet retaining some faint traces at least of a schistose structure. Is it reasonable to suppose, that a little deeper excavation would disclose perfectly well characterised granite ? The light which I fancy this spot throws upon this theory, is the most interesting circumstance connected with this deposit.

## *Worcester County Gneiss.*

The broad ranges of gneiss in the central parts of the State, which for distinction's sake may be called the Worcester county ranges, next claim attention. That range, which lies west of the mica slate deposit in Worcester valley, extends across the whole of Connecticut to Long Island Sound on the south, and probably through all the western part of New Hampshire, and I know not how much farther north. The most elevated point of this range in Massachusetts is Wachusett mountain, in Princeton, which rises 2000 feet above the level of the ocean. This is a remarkable insulated peak, nearly twice as high as any other part of Worcester county. Its stratification does not exhibit much of that irregularity, which we should suppose must have resulted from its having been elevated so much above the surrounding country : though its stratification is certainly very obscure. And I am rather inclined to ascribe such an origin to this mountain, than to suppose the surrounding country to have been once equally elevated and subsequently worn away; since the rock composing it possesses no peculiar power of resisting disintegration and abrasion, that is not possessed by the gneiss of the whole range.

I would repeat here, however, a remark made under diluvium, that the gneiss rock of Massachusetts appears to be peculiarly liable to disintegration; especially where it abounds in sulphuret of iron. Hence it is that the gneiss region of Worcester county furnishes so excellent a soil. As we go westerly upon this range, and get into the limits of Hampshire and Franklin counties, more of the naked rock appears; and the soil generally is much poorer. But in Worcester county generally the rock appears in place but seldom ; and the hills are much rounded. In the gneiss region of Hoosac mountain, that has been described, the hills are generally steeper, and the country for the most part more elevated. The soil also, is not as rich or deep as in Worcester county.

Porphyritic gneiss prevails extensively along the western margin of the Worcester county gneiss range, in the town of Northfield, Mass., and Winchester, N. H. It appears also very conspicuously on the high hill east of Ware village. This is one of the most rocky spots in the State ; and the crystaline masses of feldspar are here unusually large. This range of porphyritic gneiss extends northerly through Dana, Petersham, &c., lying immediately east of the hornblende slate exhibited on the Map. It can be traced south from Ware also, through Palmer, &c. Indeed, it is the most extensive deposit of this variety of rock I have ever found. It appears that the peculiar causes that produced it, operated over a great extent. Judging from the great regularity of the rock formations in this country, I predict that a strip of it may be found extending northerly from Long Island Sound as far as the gneiss reaches.

From Hubbardston, both north and south, to the boundaries of the State, and in breadth several miles, the characters of the gneiss are greatly obscured by the iron aspect which the rocks have assumed in consequence of the decomposition of pyrites. The same appearance is frequent in other parts of the range.

Granitic gneiss abounds in various parts of this deposit : but rather more I think in the southern than in the northern part of the State. In the west part of Charlton, for instance, and so occasionally all the distance to Brookfield, one is often at a loss whether the rock be gneiss or

granite. In Uxbridge, in the range east of the mica slate, the same variety abounds; and still more frequently on the east side of the Blackstone in Mendon.

That range of the Worcester county gneiss just referred to, which extends northeasterly into Middlesex county, possesses some peculiar characters. In another place I shall attempt to show, from the dip and direction of the strata, that it belongs to a different system of stratification from the gneiss west of Worcester valley. But I refer now to other peculiarities. One is, that it contains numerous beds of limestone, which are entirely wanting in the western range. Another is, that it passes so frequently into mica slate; the two rocks often alternating, and indeed, in some places, the slate predominating. Indeed, it would not be strange if some future geologist should regard a part of this range as mica slate. A third peculiarity is, that it abounds, especially towards its northeastern extremity, in veins and protruding masses of granite.

I have found it very difficult to determine the exact eastern limits of the gneiss range under consideration. I mean the line of its junction with the granite. Much of the gneiss near that line is granitic, and of course difficult to be distinguished from granite. In some places the beds and veins of granite increase in number and size as we go easterly, until at length the gneiss occupies only a small proportion of the surface. Near the junction of the two rocks, also, diluvium is very abundant: which increases the difficulty of fixing their limits. On the present edition of the Geological Map, I have extended this range of gneiss considerably farther east than before: and in doing this, I have perhaps included a belt of country which has more of granite in it than of stratified rocks. Yet as the latter do extend at least as far east as I have marked this formation, I thought it best to consider the whole as a gneiss deposit, abounding in veins and protruding masses of granite.

### *New Bedford Gneiss.*

The southeast part of Massachusetts is so nearly level, and the amount of drifted materials so great, that it is nearly impossible to fix with accuracy the boundaries of the different formations. I do not flatter myself that the gneiss around New Bedford is marked on the map with accuracy. But it is given as near the truth as I am able, with the materials in my hands, to make it.

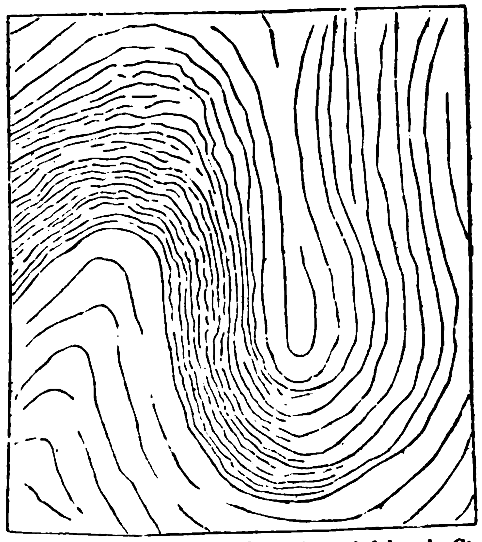
Almost all the varieties of gneiss that have been described, may be found in the vicinity of New Bedford. In that place it is schistose, and passes into mica slate. There, too, we find a beautiful variety of porphyritic gneiss in bowlders; the masses of feldspar being flesh red and about the size of a hazle nut.

### *Schistose and Stratified Structure: Strike and Dip of the Strata.*

In no rock in the State are the slaty and stratified structures so distinctly marked in the same rock, as in gneiss. The strata are frequently thick; and where no local cause of irregularity exists, remarkably even and continuous. Hence the facility with which the quarrymen cleave out slabs of gneiss, 20 or 30 feet long, and half as many wide. But these same slabs, when dressed, often exhibit a laminated structure of remarkable irregularity,—the laminæ being much bent and composed of different ingredients, so as to give to the rock the appearance of a variegated or clouded marble. The underpinning of most of the buildings in Amherst, particularly of the village church, exhibits this appearance most strikingly. The rock, however, will not cleave in the direction indicated by these contorted layers, any easier than in other directions.

The following sketch exhibits a very striking case of this foliated structure, as it is developed on the surface of a bowlder, several feet square, lying by the side of the road in Colebrook, Ct., a few miles south of the Massachusetts line. These curvatures are much larger than is usual and more distinct. They appeared to be entirely independent of the stratification.

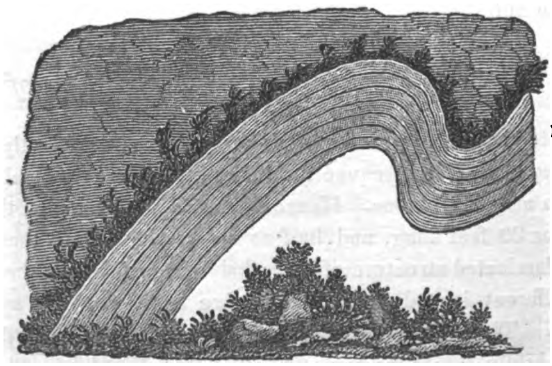
Fig. 131.



*Curvatures in the Folia of Gneiss: Colebrook, Ct.*

These curvatures are not, however, confined to the laminæ of gneiss, but are sometimes seen in the strata. About one mile before reaching the meeting house, near the center of New Marlboro gh, on the south side of the road, the traveller will see an overhanging ledge of stratified gneiss, dipping from 40° to 50° east, whose edges are bent as in the annexed sketch. The whole length of the strata here exhibited, (from A to B,) is 12 feet; and their breadth about four feet.

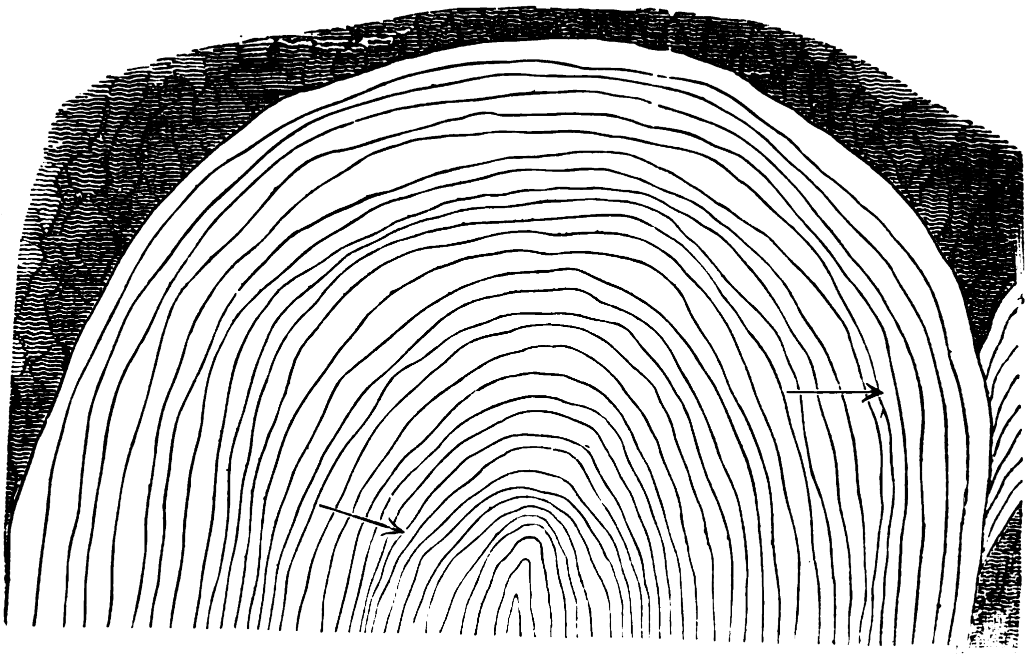
Fig. 132.




A *Curved Strata of Gneiss: New Marlborough.*

On the common in Sandisfield, around the meeting house, we find these curvatures in the gneiss on a large scale. On Fig. 133, they are shown as they appear on the northwest of the meeting house. The length of the space exhibited is 7 to 8 rods: and although I pretend not to exhibit the precise form of the curvatures, yet the drawing shows their general form and arrangement. The dip of the strata in two places is shown by the arrows.

Fig 133.

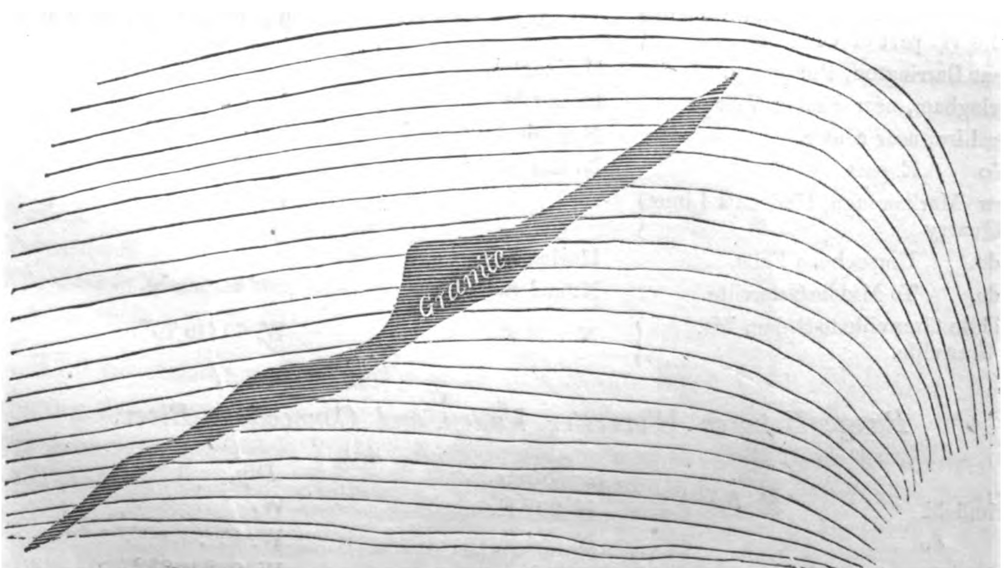


M. H.

*Curvatures in the Strata of Gneiss: Sandisfield.*

Fig. 134.

E. 15° N.




S. 20° E.

*Curved Strata of Gneiss: Sandisfield.*

Fig. 134 exhibits the strata on the east side of the meeting house, over an extent of about 4 rods in length. The curvature of the outer strata amounts to about 85°: that is, their strike on the north and east sides, varies by that quantity. A vein of granite nearly crosses the spot: but it seems to have had no concern in producing the curvatures. It is possible, indeed, to explain them by supposing an elevating force beneath that hill, which curved the strata upwards; and then conceiving them to have been deeply denuded. But I rather incline to the opinion that a lateral force must have operated, perhaps conjointly with an elevating one, to fold the strata while in a yielding state.

## Strike and Dip of the Strata.

It will appear from the following notes, relative to the dip and strike of the strata of gneiss in Massachusetts, that this rock conforms to at least five systems of stratification. The Hoosac mountain range, and the western part of the Worcester County range exhibit two systems; the branch of this latter range, which extends into Middlesex County, belongs to a third: that portion of it in the southeast part of Worcester County and in Rhode Island seems to belong to a fourth, and the New Bedford gneiss to a fifth. But more of this hereafter.

### Hoosac Mountain Range.

| | Strike. | Dip. |
|---|---|---|
| Windsor to north part of Peru. | N. and S. | East. |
| Chester to Becket. | N. and S. | 80° to 90° E. |
| Colebrook, Ct. to W. Granville. | N. and S. | Nearly 90° E. |
| Whitingham, Vt. | N. and S. | 30° W. |
| Wilmington, Vt. | N. 30° E. | 30° to 70° West. |
| do. to Somerset. | N. and S. | W. large. |
| Buckland. | N. and S. | 10° to 20° E. and 10° to 20° W. |
| | The latter rather predominating. | |
| Otis, W. part. | N. and S. | E. 25° |
| Washington, W. part from thence to the W. part of Chester. | do. | 90° E. nearly |
| Great Barrington, Purgatory. | Horizontal. | |
| Tyringham, near Shaker Village. | E. and W. | S. 20°. |
| Cheshire, near center. | N. a few degrees E. | E. 70° to 80°. |
| do. E. part. | N. and S. | E. 20° to 30°. |
| New Marlborough, Hadsell's Lime Quarry. | do. | E. 30°. |
| do. Umpachena Falls. | Horizontal. | |
| do. To Middle Granville. | N. and S. | 90° E. nearly. |
| Middle Granville to Sodom Mt. in Granville. | N. and S. | W. 60° to 70°. |

### Range Between Worcester Valley, and Connecticut River.

| | Strike. | Dip. |
|---|---|---|
| Brimfield. | N. 20° E. | W. |
| do. | N. and S. | W. 45°. |
| do. to Sturbridge. | do. | W. 20° to 80°. |

| | *Strike.* | *Dip.* |
|---|---|---|
| Between S. Wilbraham and Monson. | N. and S. | W. 45° to 70°. |
| Monson, quarry, N. W. of center. | N. several degrees E. | 90°. |
| Wales and Holland. | N. and S. nearly. | W. 60° to 80°. |
| Palmer to Sturbridge. | N. a few degrees E. | N. W. 45° to 70°. |
| Ware, Hill south of village. | N. E. and S. W. | N. W. |
| do. to Royalston, through Enfield, Dana, Petersham, &c. | N. a few degrees E. | W. decreasing northerly. |
| Southbridge to Webster. | N. E. and S. W. nearly. | N. W. |
| Dudley to Sturbridge, through Southbridge. | do. | N. W. 10° to 50°. |
| Barre, 4 miles E. of center. | | Westerly. |
| do. W. part. | Nearly horizontal. | |
| Pelham, W. side of hill. | N. and S. | W. small. |
| do. E. side of hill. | do. | E. 30.° |
| Warren to Spencer. | | W. diminishing: at Spencer nearly horizontal. |
| Charlton to Worcester on R. Road. | N. and S. | E. not more than 10° or 15°. |
| Leicester, 1 mile E. of Clappville. | E. and W. | N. small. |
| Shutesbury to Gardner through Petersham and Templeton. | N. and S. | W. 30° to 90°. |
| Northfield near Mouth of Miller's R. | N. E. and S. W. | N. W. 45°. |
| Montague. do. | N. a few degrees E. | N. W. 20°. |
| do. for 4 or 5 miles easterly. | N. E. and S. W. | N. W. |
| Thence farther east. | N. and S. nearly. | Easterly. |
| South Orange. | do. do. | 90°. |
| Between Orange and Royalston. | do. | W. 20° nearly. |
| Royalston and Athol generally. | N. 20° E. | 90° nearly. |
| Athol to Orange. | N. a few degrees E. | E. 70°. |
| Northfield, S. Mountain, W. Side. | N. and S. nearly. | E. 0° to 30.° |
| do. towards Warwick. | N. several degrees W. | E. large. |
| Warwick E. line to Royalston. | N. and S. nearly. | E 90° nearly. |
| Royalston and Winchendon. | do. | E. small. |
| Ashby, tending to | N. E. and S. W. | W. 10° 15°. |
| Townsend W. village to the Harbor, | S 30° W. | S. E. to 25°. |
| S. Royalston to Westminster. | | W. moderate. |
| Westminster, Cross Road E. part | Horizontal. | |
| do. near do. | | E. 20° to 30°. |
| Rutland to Princeton. | N. and S. nearly. | E. 50° to 10°. |
| Princeton, E. base of Wachusett Mt. | do. | do. |
| Fitchburg to Westminster. | do. | E. small. |

The preceding strikes and dips in this range have been obtained chiefly during my re-survey of the state; and because made with much care, and after greater experience, I place more confidence in them, than in the following obtained in the former survey. There is, however, a general agreement, but the observations in most cases were made in different parts of the same town, from those in the preceeding list, and it should be recollected, that the

strike and dip, in most of the region embraced by this range, is very irregular. I think, however, that I have at least been able to generalize the observations. But the results will be given in a subsequent place.

| | | |
|---|---|---|
| Sturbridge to Charlton. | N. and S. | 45° W. |
| Monson to Sturbridge through Wales and Holland. | N. and S. | 45° to 70° W. |
| Plumbago Mine, Sturbridge. | N. 30° E. | 60° to 70° N. W. |
| Oxford, West part. | N. and S. | 10° E : usually W. & large. |
| Charlton to Brookfield. | N. and S. | 20° to 40° E. |
| Warren. | N. and S. | Nearly 20° S. |
| Enfield. | N. and S. | 90° nearly. |
| Spencer, center. | N. and S. | West small. |
| do. two miles east. | N. and S. | 20° E. |
| Hardwick. | N. and S. | 20° to 30° W. |
| do. to Spencer. | N. and S. | 20° W. |
| New Braintree. | N. and S. | 20° to 30.° W. |
| Ware. | N. and S. | 20° W. |
| Pelham, West part. | N. and S. | 20° to 30° W. |
| do. North part. | N. and S. | 15° to 20° E. |
| do. to Prescott. | N. and S. | 20° to 30° E. |
| Shutesbury. | N. and S. | 45° to 90° E. |
| do. Lock's Pond. | N. W. and S. E. | 45° N. E. |
| Leverett, north part. | N. W. and S. E | 0° to 45° N. E. |
| Petersham. | N. and S. | 40° to 50° W. |
| Hubbardston. | do. | 30° W. |
| Rutland. | do. | E. very small. |
| Princeton, embracing Wachusett. | do. | 10° to 20° E. |
| do. towards Sterling. | do. | Nearly horizontal. |
| Warwick. | Between N. W. and North. | Easterly. |
| Warwick to Royalston. | N. and S. | 60° to 80.° E. |
| Winchendon W. part to Ashburnham. | do. | West, various. |
| Ashburnham to Fitchburg. | do. | West, small. |
| Townsend to Rindge, N. H. | N. 30° E. | 10° to 25° N. W. |
| Rindge, N. H. West part. | N. and S. | 30° to 40° W. |
| Winchester, N. H. towards Northfield. | do. | 20° to 30° E. |

### *Range East of Worcester Valley: North part of the Range.*

| | *Strike.* | *Dip.* |
|---|---|---|
| Bolton. | N. E. and S. W. | 60° to 70° N. W. |
| Boxborough, limestone quarry. | do. | do. |
| do. West part. | do. | 90.° |
| Carlisle. | do. | 60° to 90° N. W. |
| Chelmsford, limestone quarry. | do. | 70° to 80° N. W. |
| Worcester to Berlin. | do. | 20° to 90° N. W. |
| Concord. | N. and S. nearly. | Nearly 90° W. |
| Worcester, southeast Part. | N. several degrees E. | 70° to 80° W. |
| Dracut, Gneissoid Rock, E. part. | N. a few degrees E. | S. Easterly. |

| | Strike. | Dip. |
|---|---|---|
| Lowell. | N. E. and S. W. | 90° nearly. |
| Beverly, Hornblendic gneiss passing into Sienite, Sea shore. | do. | N. W. large. |
| Andover, Soapstone Quarry. | do. | N W. |
| Lynnfield, | do. | N. W. 45°. |
| Pepperell, 3 miles towards Dunstable. | do. | S. E. |
| From thence to Tyngsborough. | do. nearly. | do. |

## *South part of the Range.*

It is clear that in the southeast part of Worcester County a new system of elevation interferes with that running S. W. and N. E. nearly across the state, as the following statements will show.

| | Strike. | Dip. |
|---|---|---|
| Sutton, N. part. | N. W. and S. E. | N. E. |
| do. a little farther south. | N. E. and S. W. tending to E. and W. | N. W. |
| do. from center 3 or 4 miles S. | E. and W. | N. small. |
| do. a little farther S. | N. W. and S. E. | N. E. 25° to 30°. |
| do. Purgatory. | S. E. and N. W. | N. E 25°. |
| do. a little west of center. | E. and W. | N. 30° to 35°. |
| Between Webster and Franklin. | N. W. and S. E. | N. E. 20° to 30°. |
| Franklin, 2 miles W. of center. | do. | N. E. |
| West Medway. | E and W. | N. 15° to 20°. |
| Holliston to Sherburne. | N. W. and S. E. | N. E. large. |
| Bellingham to Uxbridge. | N. E. and S. W. | S. E. 30° to 60°. |
| Worcester to Grafton. | S. several degrees W. | 45° to 90° W. |
| Grafton to Upton. | S. E. and N. W. | N. E. small. |
| Mendon. | do. | 20° to 30° N. E. |
| Douglass. | do. | 25° to 30° N. E. |
| Westborough to Hopkinton Springs. | do. | 30° N. E. |
| Uxbridge. | E. & W. to S. E. & N. W. | 25° N. E. |
| Burrillville and Smithfield, W. part. | Nearly E. and W. | 25° to 30° N. |

## *New Bedford Gneiss.*

| | Strike. | Dip. |
|---|---|---|
| New Bedford, (town.) | E. 20° N. | 55° N. W. |
| do. Palmer's Island. | E. and W. | 35° N. |
| Rochester. | E. and W. | 35° N. |
| Little Compton, R. I. | N. E. and S. W. | 35° S. E. |
| New Bedford, 2 miles W. of town. | N. W. and S. E. | S. W. |
| do. | E. and W. | 90°. |
| do. to Rochester. | do. | N. large. |

## Mineral Contents.

In some parts of the world gneiss is remarkable as the repository of a number of the precious stones. In Ceylon, for instance, where gneiss is the prevailing rock, it contains of the quartz family, rock crystal, amethyst, rose quartz, cat's eye, prase and hyalite; also topaz, schorl, pyrope, cinnamon stone, zircon, spinelle, sapphire and corundum. (*Geological Transactions, Vol. V. p.* 318.) Hitherto the gneiss of Massachusetts has not yielded so rich a supply. But it affords enough of the same minerals, to prove a strong analogy between the causes that produced these deposits in parts of the globe so widely separated. Especially will this be true, if we regard the limestone beds in the northeast branch of the Worcester gneiss range, as a part of this formation; and this is certainly reasonable. For in these beds have been found spinelle, a garnet which is probably cinnamon stone, asparagus stone, nephrite, and precious serpentine; and the following statement will show that several others of the Ceylon minerals have also been found in the gneiss itself.

The most important mineral hitherto found in our gneiss, is graphite. As described in the first part of my Report, its richest locality is in Sturbridge. It occurs in other places, however, as in North Brookfield, in Brimfield, in Hinsdale, in Washington and New Marlborough, in gneiss. The plumbago in Sturbridge, which is situated only two miles north of the Connecticut line, and near the western line of the town, has been explored in some places to the depth of 60 or 70 feet. I have already described it so fully, as to render it necessary to add only a few remarks respecting its geological situation and mineralogical characters and associations. It is most decidedly a bed in a dark colored gneiss, which here dips from 60° to 70°. West, and runs N. 30° East, and S. 30° West. In immediate contact with the gneiss, we find frequently lamellar brownish hornblende, which is also disseminated to a considerable extent in the gneiss.

The luster of this plumbago is highly metallic. Its structure is between scaly and fine granular. Sometimes, however, there is an obvious approximation to distinct crystals: the mineral being in distinct plates.

There is another variety found at this locality, which is apparently fibrous: the fibres being from one to two inches long. On examination these fibres are found to be composed of distinct lamellæ, which are sometimes so bent as to give the mass a fibrous appearance; as happens in certain varieties of mica slate: but more commonly these lamellæ actually separate longitudinally into very narrow prisms, like prismatic mica. (No. 1074.)

One mile northeast of the deep cut in the Western Rail Road at the summit level, and in the town of Washington, a bed of plumbago exists in gneiss. At the surface it can not be over two feet in width; and it is a good deal mixed with the rock. The strata there are nearly perpendicular, and the spot is near the top of a high and steep hill; so that it would be most favorable for exploration. It certainly deserves to be examined: as a good mine of plumbago is invaluable.

At the Sturbridge mine of graphite I noticed phosphate of lime in a small quantity. At the most southerly excavation, also, I noticed hydrate of iron in a cross fissure in the gneiss, and forming with the ingredients of the rock a brecciated mixture. Vegetable relics are sometimes seen enveloped in the mass. Half a mile north of the Meeting House in North Brookfield, I noticed a similar breccia, forming a bed in gneiss a foot or two in thickness: though here I saw no vegetable remains.

In both these cases I think we must regard this iron ore as having been infiltrated into cavities in the gneiss, at a recent date; and therefore, in fact, as an alluvial deposit; although at Brookfield the iron forms a distinct bed in the gneiss. But the rock contains abundance of decomposing sulphate of iron, which, as we have already seen, produces bog iron of exactly the

same aspect as that above described; and it is not impossible that from this cause a cavity in the rock that was originally small, might have been much enlarged; while the exfoliated fragments would go to make up the brecciated mass above described.

It will be well for observers to bear in mind a remark of Dr. Davy relating especially to the gneiss of Ceylon. 'It is worthy of remark,' says he, 'that graphite is generally found in company with gems. I have had so often occasion to make the observation that I now never see the former without supposing the presence of the latter.' (*Geological Transactions, Vol.* 5. *p*. 323.)

The preceding remark was contained in my former Report; and since that time, I have discovered in the plumbago obtained on the farm of Mr. Morse in Sturbridge, one and a half mile south of the meeting house, the beautiful pyrope which has been fully described on page 188 of the present report. Its other numerous localities are there also described. I have found too the rich beryl of Royalston in gneiss: although as this occurs in a large vein of granite, I shall describe it under that rock.

On page 220, will be found a full account of the localities of efflorescing alum, upon the gneiss of Worcester county.

A mineral occurring in our gneiss, and often confounded with graphite, is the sulphuret of molybdenum. I have noticed this in Brimfield in scales; and in the north part of Shutesbury, a little east of Locke's pond, it has been found in hexagonal plates nearly an inch in diameter. It occurs also in a bowlder in the gneiss of Pelham. (No. 2330.)

The foliated masses of feldspar in the porphyritic gneiss passing through Brimfield, Ware, &c., are frequently a delicate adularia. In Southbridge, in a decomposing ledge of gneiss, near the center of the place, the feldspar is of a delicate green, yet almost transparent; being quite elegant when polished. (No. 1086.) In cavities in the gneiss of Boxborough, I found distinct, yet not handsome crystals of feldspar. The same occur with actynolite, augite, and sphene, in Pelham.

Common schorl is frequently seen in the gneiss of Massachusetts, as in Athol, Pelham, and New Braintree. In the latter place, the crystals have distinct acuminations. Often, as in Athol and Pelham, epidote, sometimes in crystals, is associated with the schorl.

In the New Bedford gneiss, as I was informed by T. A. Greene, Esq., epidote occurs along with rutile. In the gneiss in Pelham, I have noticed some crystals of spheneas just mentioned. But the sphene which I found in the augitic gneiss in the east part of Lee, is finer than any I have met with in New England. (No. 1091.) The crystals are very oblique rhombic prisms, variously modified; resembling those represented on Plate 12, Figs. 47, 48, and 49, of Beudant's Mineralogy.

It has already been repeatedly stated, that sulphuret of iron is one of the most abundant of the minerals in the gneiss of Worcester county. In Hubbardston, as I have mentioned elsewhere, this ore is used for the preparation of copperas.

Magnetic oxide of iron is sometimes met with in small disseminated masses in gneiss, as in Athol and Shelburne.

Arsenical sulphuret of iron is said to occur in Leicester in gneiss.

In Pelham, Enfield, Belchertown, Phillipston, &c., we meet in this rock, with well characterised specimens of anthophyllite.

In Pelham, also, is a great abundance of finely crystalised quartz. Some of the crystals are quite delicate. They are commonly limpid, though sometimes of a light brown color, and sometimes of a fine topaz yellow, being genuine yellow quartz. Rarely are they amethystine. Not unfrequently large cavities are drusy, and present fine specimens. The crystals vary in size, from two inches in diameter to the fineness of a sewing needle. It is not easy to ascertain the precise situation of this quartz in the gneiss; since it is seen only in loose masses scattered over

several acres. Probably, however, it constitutes a vein. I observed no metallic substance in it, except a little sulphuret of iron.

Associated with this quartz are found beautiful specimens of mammillary chalcedony. (No. 1102.) Rarely it is of a milk white color; but commonly of a delicate blue. Sometimes it may be seen investing distinct crystals of quartz, thus showing its origin to be watery infiltration beyond all question.

In West Brookfield smoky quartz has been found, though I know not whether in much quantity, which, when cut, is an elegant ornamental stone.

In Pelham a rather handsome yellow beryl has been found in the gneiss: but not abundant. In the gneiss of Franklin, as already described on p. 185, we have a delicate amethyst. This occurs about two miles west of the meeting house: but at present the locality seems to be exhausted.

It has already been mentioned that steatite and serpentine occur in beds in our gneiss. In Millbury, a variety of the former has been found, which has been called *vermiculite*, on account of its singular property of shooting forth vermiform masses when exposed to heat: thus giving to the specimens, when in the fire, the appearance of worms in motion.

One mile and a half north of Brimfield center, on the road leading to Warren, and near the house of Samuel Patrick, the gneiss rock, where it has been blasted to improve the road, has afforded quite a number of specimens of iolite. (No. 2310) It is massive, and the masses small; but it has the delicate blue color, foliated structure, hardness, and other characters, of iolite. In the same rock is beautiful adularia, of delicate yellowish color. (Nos. 2311, 2312.) We find there, also, small prismatic masses of sulphuret of molybdenum; a mineral which is found very frequently with the adularia of Brimfield, in other parts of the town. Until more rock is blasted, this locality will afford but few more specimens of the iolite.

A mile east of the locality of beryls in South Royalston, on the road to Templeton, I found a bowlder of gneiss, which contained a large number of crystals of Allanite; which is essentially an oxide of cerium. (No. 2324.) The crystals are prisms, often two inches long, which appear to be right oblique angled prisms, truncated upon the acute edges, so as in fact to become six sided prisms. Their diameter is rarely a quarter of an inch; but usually much smaller. I have yet found no one with distinct terminations. The fracture is eminently resinous, and all the external characters correspond to the Allanite from Greenland. Indeed, specimens are frequently found that cannot be distinguished from the orthite and pyrorthite of Sweden; which are probably the same mineral. In passing from the beryl locality in Royalston to Athol, I found the Allanite in the latter town, in the same variety of gneiss as in Royalston. (No. 2325.) And quite recently, Alden Spooner, Esq., of Athol, writes me, that in opening a new road from that place to Westminster, the rocks blasted out frequently contained crystals of this mineral: so that I have strong hope that it will be found in considerable abundance in that region. On the same road, vast quantities of a mineral were thrown out, which Mr Spooner regards as fibrolite. Wagon loads of the specimens, he says, may be obtained. The rock in which it occurs, approaches mica slate in its characters, as it does in Phillipston, where the same mineral occurs.

Another mineral is frequently found in the form of pebbles among the diluvium of Athol and Royalston, and even southerly as far as Barre, which I pretend not to name. Its color is usually white, sometimes brown, its hardness equal to that of quartz, and its toughness much greater. It is fibrous when broken. (Nos. 2331, 2332.) It may not be connected with gneiss, as other rocks lie to the northwest of Athol, from whence it must have been drifted.

The region in the north part of the State, embracing the towns of Royalston, Athol, Orange, Erving, and Warwick, appears to me to promise very much to one who has leisure carefully to investigate its mineralogy. I feel as if the exploration had yet been only begun.

Near the factories at Three Rivers in Palmer, small but well defined crystals of feldspar oc-

cupy drusy cavities in the tortuous gneiss. The crystals usually exhibit the primary form, with only a slight truncation on the solid angles; as shown on Plate 11, Fig. 19, of Beudant's *Traite de Mineralogie.* The specimens (2317, 2318,) exactly resemble the same mineral from near Arendal in Norway. Crystals of feldspar are also found along the Western Rail Road in Middlefield and Washington.

In the same rock at Three Rivers, we find occasionally, imperfectly crystalised prehnite and perhaps zeolite. (Nos. 2319, 2320.) These are connected with beautiful laminated masses of reddish calcareous spar, in which also, we sometimes find crystals of feldspar imbedded. (Nos. 2321, 2322, 2323.) In the gneiss of Wales, is sometimes found limpid Iceland spar of sufficient size to show double refraction well.

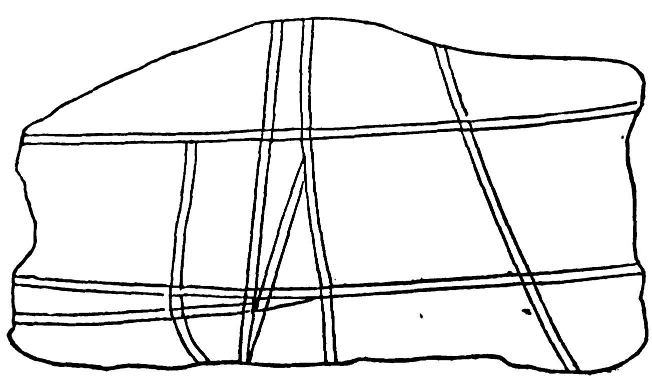
On the gneiss in the extreme west part of Barre, there occurs rutile, in small delicate prisms, along with crystalised mica and sulphuret of iron. (No. 2313.) Crystalised mica also exists in Mendon, in connection with chlorite, near Blackstone Village. (No. 2326.)

The beautiful mass of hornstone, (No. 2509,) used in time of Shay's insurrection to furnish flints to his party, I have referred to the gneiss formation, because it was found lying upon it, and I know of no other rock north of the spot where it was found with which it could have been connected. It must have answered as a substitute for flints extremely well, as it strikes fire with steel admirably.

## Veins in Gneiss.

The common injected veins in gneiss, such as those of trap and granite, will be described, when there is any thing about them needing description, under unstratified rocks. But some parts of the gneiss formation in the northeast part of the State, exhibit the most remarkable examples of segregeted veins that I have ever seen. The most striking spot where I have seen them, is in the northwest part of Andover, not far from the Merrimack, on the road to Lowell. I am not sure whether the rock there is gneiss or mica slate, as the spot is near the limits of those rocks; and it is often difficult to say which predominates. In Lowell I noticed these veins in gneiss; and Fig. 135 exhibits a bowlder, which I found near the Powder Mills on Concord river. The block is only about 5 feet long, and the number of veins is far less than is common. They are frequently so numerous as to give the surface the reticulated aspect of a large fish net. It will be seen that these veins do not cut off one another, or produce any mutual disturbance; and by these marks they are easily known from injected veins. They consist simply of harder portions of the rock, and would hardly be noticed, had not disintegration affected the surface.

Fig. 135.



## UNSTRATIFIED ROCKS.

I have already described several rocks, (ex. gr. limestone, serpentine, and one or two varieties of hornblende slate,) as sometimes stratified and sometimes unstratified. But the rocks which I include under the present division, are never stratified in the proper sense of that term. They are, indeed sometimes divided into parallel masses; but in such cases this peculiar form seems to result from that kind of crystaline arrangement called the concretionary structure. The question so long agitated, whether these rocks, particularly granite, are stratified, seems at last to be satisfactorily settled in the negative. This character, therefore, may with propriety be employed to designate one of the great classes of rocks.

Unstratified rocks occupy but a small part of the surface of any country. In Great Britain Macculloch says they 'do not cover a thousandth part of the superficies of the island.' In Massachusetts, however, as may be seen by the map, they form a much larger part of the surface.

There would be some advantages in treating of these rocks in an ascending, instead of a descending order: that is, in beginning with granite, taking sienite next, porphyry next, and greenstone last. For this is the order in which in general they seem to have been produced. But for the sake of uniformity, and to secure some other advantages, I shall invert this order.

A few words may be needful in this place, in respect to the manner in which these rocks are represented on the map. From the intricate manner in which the greenstone, sienite, and granite are mixed together, in the vicinity of Boston, I found it impossible to give them precisely their true relative space in the delineation. I therefore colored the whole space occupied by them all, as granite; and then, having observed that as a general fact the greenstone was first met with, on lines radiating from Boston, then porphyry and sienite, and lastly granite, I represented these several rocks as occupying spaces somewhat in the form of concentric bands. Wherever I observed these rocks intermingled, however, I have endeavored to represent their mixture by scattering dots and crosses somewhat promiscuously in the region. This method of course can give only an approximation to the truth. In the valley of the Connecticut, these rocks are scarcely ever so confusedly mixed together; and, therefore, it is only in the eastern and north-eastern parts of the State that such a course has been adopted.

### 15. GREENSTONE.

The most approved definition of this rock makes it to consist of hornblende with compact and common feldspar. A mixture of hornblende and feldspar, the former in much the largest proportion, and both of the minerals exhibiting but little of a crystaline structure, constitutes the great mass of the trap rocks of Massachusetts. Other varieties do indeed occur, composed of different ingredients: but as these are found in such small quantity, and are obviously accidental varieties, I have thought it most judicious to describe them all under the term greenstone. Such

a liberty I have frequently taken in the case of the stratified rocks; and I think it still less objectionable in the case of the unstratified; because there is much more diversity of opinion among geologists as to the ingredients that compose the latter. These ingredients are often so little crystaline, as to be exceedingly obscure in their characters; and it is, therefore, no wonder that such diversity exists even in the statements of the ablest writers. Especially is this not surprising, when we recollect, that until recently, it was thought essential to a good description of these rocks, that the observer should be able to prove that they belonged either to the primitive, transition, or secondary class of the stratified rocks. It was bad enough to be obliged to stretch the stratified rocks upon this Procrustean bed, although here these artificial divisions had some appearance of naturalness; but in the unstratified rocks, no facts could be found on which to base such an arrangement; and, therefore, imagination must supply the necessary characters. The consequence was, that minute and ever varying mineralogical characters in the trap rocks were studied with scrupulous exactness; while their geological position and chemical and mechanical influence on other rocks, were scarcely noticed.

## *Lithological Characters.*

1. *Hornblende and Feldspar:* the mixture more or less granular. Commonly the ingredients are so fine that they are with some difficulty discerned by the naked eye. Hence it is not easy to determine always whether the feldspar is compact or foliated. Frequently I believe, however, that both varieties will be found, and that often in the same specimen. The crystaline structure of the hornblende is usually very indistinct. In the eastern part of the State, however, where this rock is associated with sienite, the two ingredients are often very distinct and the texture crystaline. A variety occurs on Mount Holyoke and in West Springfield, in which the ingredients are very coarse, and the feldspar, which is foliated, is of so dark a color as with difficulty to be distinguished from the hornblende. (Nos. 1127, 1128) The feldspar is arranged in stripes, like a ribbon, as in the sienite near Boston.

The compound that has now been described, constitutes the principal part of the greenstone dikes, ridges, and hummocks, in Massachusetts. (Nos. 1106 to 1135.) The same compound occurs also in other forms, as will be seen in the sequel.

2. *Columnar.* This differs from the preceding variety only in form: for its composition is almost uniformly the same. Nearly all the greenstone in the valley of the Connecticut exhibits more or less of a *conatus* at a columnar structure, except the tufaceous variety. Yet it is the finely granular variety, that exhibits the most perfect forms. A similar conatus appears in some of the beds of greenstone in the eastern part of the State, especially in Charlestown: but these columnar masses are so imperfect, compared with some of those in the Connecticut valley, that I shall limit my remarks entirely to the greenstone occurring in that valley: and as it is more convenient, I shall in this place give the topography of the variety under consideration.

Nearly all the ridges of greenstone in the valley of the Connecticut, (for a reason that will appear in the sequel,) present on their western sides, a nearly perpendicular face. Usually, however, the angular fragments that have fallen from these precipices, have accumulated at the bottom, so as to form a steep talus, reaching half or two thirds the distance to the summit; and sometimes entirely to the top. Where the rock appears in the face of the cliff, it is almost always more or less columnar; sometimes as much as 30 or 40 feet in height. In some cases one set of columns is separated from another set, above or below, by a stratum or mass of trap tuff.

There are, however, only a few places where these columns are very perfect. Along the west side of the greenstone ridge that forms the eastern part of Deerfield mountain, in several places, about a mile east of the village, they exhibit great regularity. Usually their diameter

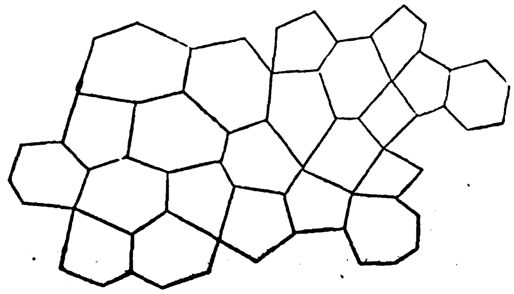
here,—and the same remark will apply to every other locality, except that at Titan's Pier, is between two and three feet; rarely as small as one foot; and the number of their sides between four and six. They are sometimes distinctly articulated; the joints varying from one to three or four feet in height. The joints are usually curved, at their ends, presenting frequently a convexity on the upper side, and a concavity on the lower. The breadth of the sides is considerably unequal; and with this exception, these columns might compare in regularity with those of basalt from Ireland.

In the second part of my Report, (p. 244,) I have given an account of the columns in the west face of Holyoke, constituting what I call *Titan's Piazza*. Figs. 12 and 13, which were there introduced, will convey some idea of the spot.

I have been at a loss to decide, whether the exfoliation which is here exhibited, takes place according to an original structure of the rock, or is produced by the natural action of the disintegrating agents; such as air, moisture, heat, and cold, upon rocks of a peculiar form. I can hardly admit the latter supposition; when, on breaking the fragments, they are found, except for a mere line at the surface, to be so entirely unchanged. Yet this curved form of exfoliation is not the only one exhibited on this greenstone range. More frequently the columns split longitudinally, into somewhat irregular pieces, from one to six or more inches in diameter. All along the western side of Mount Tom, examples of this kind may be seen; and the quantity of fragments of this sort, accumulated at the base of this mountain, is immense. Sometimes these fragments are very regular in their forms; producing prisms of three, four, five, &c., sides, and three to six inches in diameter. (Nos. 1136, 1137, 1138.) Again, as at Titan's Pier, described in the second part of my Report, concave layers of the rock (No. 1139)cleave off from the upper extremity. A joint of this description will sometimes contain several quarts of water; and I have seen one of them standing by a farmer's well, which was used as a substitute for a wash-bowl! Upon the whole, I am of opinion that the form of these exfoliations depends upon original structure, which the disintegrating agents above mentioned reveal, but do not create.

I know of no spot where so good a view of the ends of these greenstone columns can be obtained, as at Titan's Pier above mentioned. They are exhibited to the best advantage on the west side of the ridge, where it passes under the river: and at low water, we can see the ends of the columns forming the bottom of the river, as far as the eye can reach. The following sketch represents above twenty of these columns, as they present themselves at low water, and close to the water, at the spot, just mentioned. The sides were not measured except by the eye, and I am confident that there is quite as much regularity in the columns themselves, as in the drawing, and probably more. The sides, it will be seen, vary from four to six. The upper ends of these columns are considerably convex: whereas only one rod farther from the water, as already mentioned, they are decidedly concave. And although it is possible that in the first case the form might have resulted from the action of the river, yet from all that I have seen, I much doubt whether the upper or lower end is uniformly convex or concave. These columns are rarely more than 15 inches in diameter.

Fig. 136.



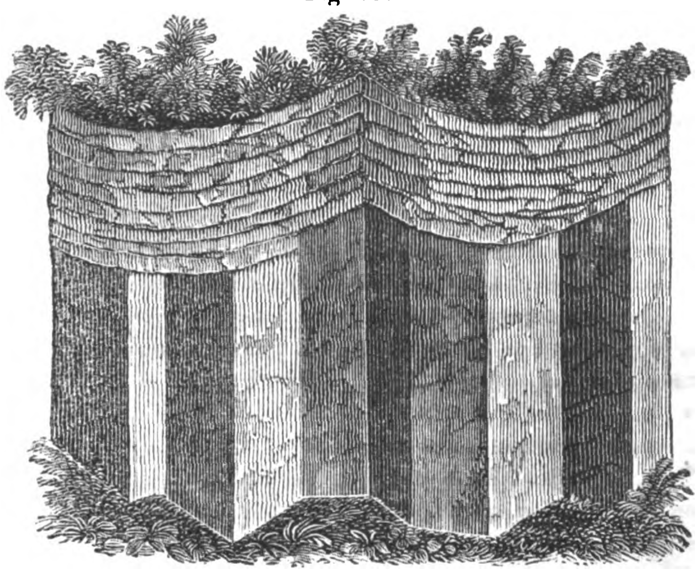
*Ends of Greenstone Columns at Titan's Pier.*

Both at Deerfield and Holyoke, one sometimes meets with columns that are considerably curved. In general they are not perpendicular to the horizon, but lean from 10° to 30° towards the east, and stand about perpendicular to the strata of sandstone beneath.

In Easthampton, at the northern extremity of the highest part of Mount Tom the greenstone columns exhibit great regularity ; and from thence I have succeeded in obtaining the large joint, No. 2510, in the State Collection. Better ones could have been obtained, were it not necessary to allow them to roll down a steep declivity of fragments of greenstone, several rods long, by which nine out of ten are broken in pieces.

At this spot there is rather an unique example, in which the columnar form does not extend through the whole mass of homogeneous rock ; but the upper part of the mass shows columnar divisions only on a large scale, embracing several of the columns below. The columnar is not succeeded as suddenly by the amorphous structure as would be supposed by Fig. 137, which gives only an imperfect idea of the spot, from defects both in the drawing and the engraving. At the lower part, the columns are very regular ; but the planes that divide them do not extend to the top of the rock, though some of them reach higher than others ; and one rises through the whole mass. And yet, the upper part is not a different variety of greenstone, as the rock is which frequently overlies columns ; but it is precisely the same as the columns. The space represented on the following figure is about 7 feet in height, and 8 feet in a horizontal direction. The upper part appears to me to be passing into a curved concretionary structure, while the lower part is an example of the columnar concretionary structure. What modification of the producing causes could have produced this difference of structure in the same mass, we may never know.

Fig. 137.



*Greenstone Columns on Mt. Tom.*

3. *Compact.* In this variety, which is almost entirely homogeneous and finely granular in its texture, the different ingredients cannot be distinguished. In some cases it is probably only indurated clay, or wacke, with some dark coloring matter : in other cases, it may be hornblende and feldspar, completely melted together. The aspect of the rock approaches closely to some varieties of basalt ; but it is doubtful whether we have any trap rock in this part of America, which was produced at the same epoch, or is composed of precisely the same mixture, as the European basalt. The variety under consideration occurs generally in the form of veins ; as at Nahant, &c. (Nos. 1140 to 1143.)

4. *Chiefly Greenish and Compact Feldspar.* This is a beautiful rock; but its characters are very obscure. Perhaps it ought to be described under porphyry; but its great resemblance to trap has led me to place it here. It occurs in Essex County along with sienite, common greenstone, &c. (Nos. 1144 to 1147.) It is traversed by veins of epidote and perhaps this gives a colour to the rock.

5. *Indurated Clay.* This variety is of limited extent; occurring only at the junction of greenstone and shale; as at Titan's Pier. In aspect it approaches to hornstone; being of a light grey color. In the same mass with this rock, we usually find angular pieces of compact trap: so that in fact it might have been described under *trap tufa.* (Nos. 1148 to 1150.)

6. *Hornblende, Augite, and Feldspar.* The hornblende in this compound is in crystaline fragments: and the mineral which I suspect to be augite, is of a greenish aspect, but scarcely crystaline. The feldspar is somewhat foliated and in small quantity. It occurs only at Nahant, a little distance northwest of the Hotel, and the most remarkable circumstance in relation to it, is its apparent regular stratification. This is the only instance that I know of in Massachusetts where a trap rock exhibits those parallel divisions. I do not, however, regard them as real strata, for reasons that will be hereafter mentioned. (Nos. 1152 to 1155.)

7. *Porphyritic.* There is considerable diversity in the composition of the rocks included under this term. Their characters and situation deserve a particular notice, since they are frequently useful for ornamental purposes. (Nos. 1156 to 1164.)

On Cape Ann a variety occurs, which resembles the black porphyry of the ancients, and appears to be the *trap porphyry* of Werner, and the *melaphyre* of Al. Brongniart. I should describe it as having a base of common greenstone, with large imbedded crystals of greenish foliated feldspar. Sometimes these crystals are more than an inch in diameter. It occurs at Sandy Bay, near the village, in veins in sienite. A similar rock is found in veins at Marblehead, according to the Messrs. Danas: also in rolled masses in Dorchester, Brookline, and Roxbury. I have noticed the same rock in rolled pieces in Easton, except that the feldspathic crystals are white. (Nos. 1156, 1157.)

In Ipswich, west part, I found a rolled mass which appears to be a greenstone with numerous foliated masses of a shining black color, which I at first suspected to be feldspar: but I am satisfied that they are *Karinthin.* (No. 1159.)

A considerable part of the eastern or upper side of the greenstone in the Connecticut valley, is very different in its composition from the principal part of the ridges. The basis of the rock is wacke-like; and some of it is amygdaloidal, and some of it porphyritic. The foliated masses of feldspar, however, are so small and so numerous, that I doubt whether it might not with quite as much propriety be reckoned as common trap. I doubt whether it contains any hornblende. Its general color is gray. (Nos. 1163, 1164.)

Occasionally we meet among the greenstone of the central part of the State, with other varieties that are more or less porphyritic. No. 1161, from Deerfield has a compact homogeneous base, nearly of the color of brick, with a few small imbedded crystals of feldspar. It is found in the same mass with common greenstone: but seems to have been exposed to a higher degree of heat. No. 1160, from Turner's Falls, has a variegated base, whose nature is not obvious, with crystals of feldspar.

8. *Amygdaloidal.* This structure, like the porphyritic, is found in nearly all the varieties of greenstone that have been described. The following are the most common of our amygdaloids, (Nos. 1166 to 1175.)

*With a base of hornblende and feldspar:* the first variety of greenstone above described. I have never seen any of this amygdaloid very regularly columnar: still it very frequently exhibits a columnar tendency. And it is a curious fact that the cavities often run lengthwise of the column, and are parallel to one another: so that the rock resembles a block of wood, which worms

or lithodomous shells have bored through repeatedly, in a longitudinal direction. I have observed some of these cavities a foot or two in length, (No. 1166.) On account of the compactness of this rock, these cavities are usually filled with foreign substances, such as calcareous spar, chalcedony, quartz, chabasie, Lincolnite, &c. The best spot that I know of for obtaining specimens of this rock, is one mile directly east of the academy in Deerfield.

In the same ledge, as well as in other ledges, the amygdaloid abounds in spherical or spheroidal cavities, filled with quartz or calcareous spar.

What particular causes produced these different forms in the cavities, it may not in the present state of knowledge be possible satisfactorily to ascertain. That they were all produced by an elastic fluid, while yet the rock was in a plastic state, seems now generally admitted. Must not the different forms which they have assumed, be imputed to inequality of pressure? And yet the air vesicles in a mass of ice exhibit the same variety of shapes, some of them being cylindrical, some spheroidal, and some spherical: nor can we in this case impute their form to inequality of pressure. But whatever the cause be, may it not be the same?

The most usual amygdaloid in the Connecticut valley has a base which appears to be wacke. It occupies, as already remarked, the easterly part of the ridges wherever I have examined them. For the most part, it is liable to partial decomposition to a considerable depth from the surface, and the imbedded minerals have entirely disappeared. When they still remain, calcareous spar is the most common. Not unfrequently, however, foliated chlorite occupies most of the cavities; and sometimes, as at Turner's Falls, they are filled with chlorophæite. Green earth, or earthy chlorite, is still more frequently present. Sometimes the base is of a reddish hue; but commonly of an earthy gray. In such cases the rock exceedingly resembles a toad in appearance, and is probably similar to, if not identical with, the toadstone of England. When the cavities are empty, the rock can hardly be distinguished from some recent lavas. (Nos. 1170 to 1174.)

All these varieties with a wacke-like base, exhale a strong argillaceous odour when breathed upon.

The greenstone in the eastern part of the State is rarely amygdaloidal.

9. *Concreted.* The argillaceous substance above described, as forming the base of certain amygdaloids, sometimes contains numerous distinct concretions of the same substance, apparently more indurated. They are generally spheroidal; and the concentric crust not more than a line in thickness. Sometimes I have observed the central nucleus to consist of a rounded mass of amygdaloid enveloped by coats of indurated clay or wacke. The diameter of these concretions is sometimes six or eight inches: but usually not more than two or three. They sometimes occur imbedded in the next variety to be discribed. Their most abundant localities, which I have noticed in Massachusetts, are in Deerfield, east of the village, and on Mount Holyoke, near the road from Amherst to Granby. (Nos. 1176, 1177.)

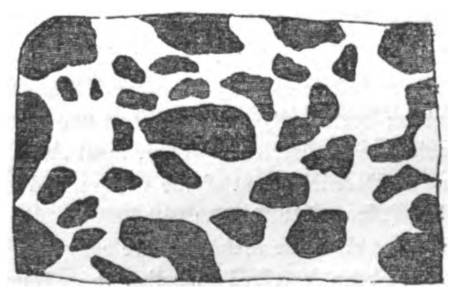
10. *Tufaceous.* This embraces all those rocks that are composed of fragments of any of the varieties of greenstone that have been described; whether these fragments are angular or rounded; united by 'trap sand,' or the same materials in a comminuted state. Sometimes, however, the rock consists of angular fragments of greenstone, cemented by calcareous spar. In this case it is obvious that the spar was introduced by watery infiltration, after the fragments had been piled together. In other cases, it is equally obvious that the fragments have been melted together: for we distinguish the different materials of which they consist, only by the different colors; it being no easier to separate the rock along the line where the fragments unite, than in any other direction: and I do not suppose it possible to unite fragments so firmly except by fusion. (Nos. 1178 to 1186.)

## *Topography of the Greenstone.*

Excepting a few small beds in Worcester County, the parts of the State in which greenstone occurs in sufficient quantity to be noticed on a Map, are only two. In the eastern and northeastern parts of the State, it will be seen that there are extensive ranges. As we pass beyond the graywacke and argillaceous slate that encircle Boston on the north, west, and south, we usually find greenstone to be the predominant rock. Even on the south, in Milton, &c. where porphyry is represented on the Map as succeeding to the graywacke and clay slate, we usually meet with narrow masses of greenstone, probably in some cases interposed among the layers of slate. On the north of Boston, in the slate of Charlestown particularly, such masses or beds of greenstone are common; In this slate also, as well as in the graywacke in other places, (as at Roxbury,) the greenstone is found in veins. At Nahant they are sometimes forty feet thick, in argillaceous slate and sienite.

If we proceed from Boston, after striking the deposit of greenstone above named, we shall soon find that it is passing into sienite, and mixed with sienite in almost every conceivable mode. In one place the greenstone seems to form a distinct vein in the sienite, the two rocks being well defined at their line of junction. In another place, the sienite seems to form veins in the greenstone; although in such cases it is no easy matter to determine which rock should have the posteriority: But from the general fact, which is obvious in this region, that the greenstone has been produced subsequently to the sienite, I think we should be cautious in reversing this order without good evidence. In some cases, however, we meet with a reddish sienite containing numerous and sometimes large angular and rounded fragments of greenstone. I give a rough sketch below, of one of these cases, which I observed in Marblehead, a little west of the town. In this case the base of the rock is rather a red granite than sienite, being entirely destitute of hornblende.

Fig. 138.



*Sienite and Greenstone: Marblehead.*

Instances similar to this are to be seen every where in the region under consideration. And they certainly appear as if the greenstone had been partially melted down in the granite; though the heat was not great enough to complete the fusion. Or rather, may it not be probable, that the perfect fusion of the rock out of which those unstratified ones were produced, gave rise to the granite: while those portions that were not so completely fused as to admit of entirely new and perfect combinations and crystalizations, might have formed those portions of the rock which I call greenstone, although some of it might as well perhaps be denominated sienite.

As we proceed farther from Boston, the sienite increases and the greenstone decreases in quantity, and we begin to find granite destitute of hornblende, which at length often becomes extremely coarse, and forms protruding masses in gneiss; as in Billerica, Andover, &c. The greenstone, however, occasionally appears associated with the perfect granite, as with the sienite; though I do not recollect any instance where the passage from the greenstone to the granite is gradual, as is the case between greenstone and sienite. Generally the greenstone forms veins in the granite. I have sometimes traced them not more than a foot or two wide for several rods, (as in Weymouth,) retaining their direction and width with almost mathematical exactness.

In the manner that has now been described, is the greenstone of the eastern part of the State intermingled with its unstratified associates, as the youngest member of the group. To mark out the precise limits of this rock in that section would require immense labor, both on account of the great quantity of diluvium that overlies the rocks, and the difficulty of drawing the line in all cases between greenstone and sienite. Nor, if it be correct that all these unstratified rocks are mere varieties of the same family, would such a demarcation be of any great use; although I could wish to see it done; since in that way many facts might be brought to light important to geology.

Rarely does the greenstone under consideration form ridges or elevations of any considerable height. In Weston, Waltham, Lincoln, Lexington, and West Cambridge, this formation attains its greatest elevation; which is never as much as 500 feet above the ocean.

The greater part of the greenstone under consideration is exceedingly hard and compact, and the ingredients are with difficulty distinguished. When passing to sienite, however, they become coarse and highly crystaline. Very frequently the rock has a greenish aspect, from a quantity of epidote which is disseminated in it, or forms narrow veins, or a coating upon the surface. It is not common, except where it is associated with the graywacke, to see it exhibit that brown dirty aspect so common in the trap rocks of posterior date.

Occasionally we find examples of a slaty structure in this greenstone. And it must be regarded as really a slaty structure, probably the result of original deposition. For the slate generally appears to be genuine hornblende slate, sometimes rather less crystaline, however, than that rock generally is. I recollect at this moment but a few places where this slaty greenstone was observed: viz. in Lincoln, on the turnpike between Andover and Boston, in Beverly, in Stoneham, and near the line between Reading and Wilmington. In a theoretical point of view this fact seems to me important.

Variety No. 4. that has been described on a preceding page, is found in connection with sienite, a mile or two north of Byfield Academy, as well as in various places in Newbury. Near the academy we find red compact feldspar: but I do not know that this is at all connected with the greenstone. On the north side of the Merrimack river, in Salisbury, opposite Newburyport, this same variety of rock occurs in juxtaposition with sienite. Its aspect not a little resembles the varioloid wacke in Saugus; and I am not without suspicion that it may be the same rock highly indurated. And it strengthens this suspicion to find that sometimes in Newbury it exhibits a varioloid structure.

The Map exhibits the most northerly of the greenstone ranges in the Connecticut valley, associated with secondary rocks; though in Vermont and New Hampshire in this valley, trap rock occurs in connection with argillaceous and mica slate. The greenstone which I am now describing, is associated with the new red sandstone; and ridges of it may be seen extending almost uninterruptedly from New Haven, Ct. to the north line of Massachusetts. The principal ridge commences with West Rock, at New Haven, and extends from thence, almost in a right line, to Mount Tom in Massachusetts. In Connecticut several other ridges and hummocks of this rock exist to the east of this principal one; as may be seen on a geological map of the Connecticut valley, which I prepared for the 6th volume of the American Journal of Science.

The principal greenstone ridge above noticed, crosses the Connecticut river between Holyoke and Tom, and curving towards the east, terminates in the northwest part of Belchertown. At the southern extremity of Mount Toby, however, we meet with another much more diminutive ridge, or dike of this rock, which almost coincides in direction with the meridian through Sunderland, and crossing the Connecticut river near the north line of that town, rises in Deerfield to a much greater altitude, forming the eastern half of that range of hills which occupies the eastern part of that town and Greenfield. In Deerfield the eastern side of the greenstone is very gentle in its slope, and precipitous on its west side. But in Greenfield, although the western side continues to present a mural face, its eastern side also is very steep; being washed by the waters of the Connecticut. This ridge terminates at Turner's Falls in Greenfield. Another parallel ridge commences at the same place, only a few rods distant but on the opposite side of a small river, (Fall river,) in Gill, and extends more than a mile towards the center of that town. Beyond the extremity of this ridge, I have not found any greenstone except that which I have described as a member of the hornblende slate formation. A deposit of this, as may be seen by the map, commences in the north part of Gill, only three or four miles north of the point where the greenstone already described terminates.

The external aspect of the greenstone in the Connecticut valley, is very different from that of the same rock in the eastern part of the State. Much of the latter is of a dark color, or when examined nearer, of a green aspect, from the presence of epidote. But the former almost universally exhibits a gray or iron rust color, either from incipient decomposition, or from the presence of oxide of iron. Yet when broken open it is greenish.

The most common variety of the greenstone in the Connecticut valley is a fine grained mixture of hornblende and feldspar. This is sometimes columnar, as already described. Not unfrequently too, it is amygdaloidal; though the more perfect this structure, the less perfect the columnar. Trap tuff is also much more frequent than I formerly supposed. Sometimes we find a mass of it overlaying a mass of columns; and sometimes it forms an irregular layer between the ends of successive stories of columns. A mile east of the village in Greenfield, a variety of tuff constitutes a large part of a ledge of greenstone, which in some places is more than a hundred feet high. I have observed this rock on the west side of Mount Tom, also on Holyoke, and various other places. It must be distinguished from the *tufaceous conglomerate*, that has been already described as a member of the new red sandstone formation, lying upon the eastern side of Mount Holyoke and Tom. The real trap tuff contains few or no fragments of sandstone; whereas in the conglomerate, the sandstone abounds. But the two rocks pass into each other insensibly.

In the gneiss range between the valleys of Worcester and the Connecticut, we frequently meet with a rock in ledges and blocks, whose composition and structure correspond closely with those of the greenstone that has been described. Indeed, the two ingredients are usually more distinct than in the greenstones associated with more recent rocks. The beds or tuberculous masses of this rock, also, that have been met with, never exhibit any tendency to stratification, or a slaty division; and hence cannot be regarded as belonging to hornblende slate. On the other hand, however, I have never met in them with a columnar or amygdaloidal structure; nor with veins proceeding from them, except perhaps in one instance in the west part of Holden. A vein, also, may be seen in the gneiss a few rods from the mouth of Miller's river in Erving's Grant. But I have not found any large masses of the greenstone with which this vein, nearly 2 feet wide, is connected. Upon the whole, however, there can be no doubt but these protruding masses are genuine unstratified greenstone.

In my former Report I noticed a few of these insulated masses of greenstone in the gneiss. But in consequence of having my attention particularly called to the subject by Dr. J. G. Percival, the state geologist of Connecticut, I have found many more examples in my examination of

the Worcester county gneiss; and these may be seen upon the geological Map. They are marked in the following places. In Pelham are two masses in place: one near the west line of the town, and the other a mile or two northwest of the meeting house. In Phillipston is a large mass in place, about a mile south of the meeting house. At Fiskdale, in Sturbridge, a few rods south of the factories, may be seen another deposit. In the west part of Holden, or the east part of Rutland, (I am not sure which,) is another: in Montague, on the west border of the gneiss formation, and 2 miles northeast of the meeting house, is another. This last deposit rises 20 or 30 feet above the general surface, and is divided by perfectly parallel planes, running nearly east and west, and standing perpendicular, into stratiform masses: a fact which I have noticed no where else; and which does not seem to me to admit of a very easy explanation.

These are all the examples in which I am certain that I have found the greenstone in place, in the region under consideration. But in many other places its blocks, but slightly rounded, occur in narrow trains, which have precisely the direction of the diluvial current; and hence they seem to me to indicate the existence of a dike of this rock, at the northern extremity of the train of blocks, almost as certainly as a continuous ledge could do it. A train of this sort may be traced from a point about a mile and a half northwest of Monson center, on the west side of the hornblende slate, in a direction several degrees west of south, to a point about two miles and a half southwest of Monson meeting house. Again, as we ascend the hill southeast of Monson center, we cross another train of blocks, of no great width. We meet with a few bowlders, as we go east, near the center of Wales; and when we reach the east part of Holland, they are quite numerous. They abound over nearly every part of Sturbridge, particularly along its western side. They are common between Sturbridge and Southbridge; and they continue, though very much scattered, as far east as Dudley. From the deposit of trap at Fiskdale in Sturbridge, northwesterly to Ware, trap bowlders are abundant; often forming a third part of the stone walls. In passing along the rail road from the southeast part of Palmer to Warren, trap bowlders, and often several feet in diameter, are common. East of Warren they are seen occasionally; but probably only as stragglers, as far as Auburn. Upon the whole, there must be a powerful dike of trap, running from Southbridge through Sturbridge and Warren to Ware, or else several dikes running northeast and southwest. I have, therefore, not attempted to fix the exact place of these dikes in the towns above named, (except that at Fiskdale,) but have merely marked them occasionally on the map to indicate that the amount of this rock there must be considerable.

Somewhat farther north, we find greenstone bowlders rather abundant in the northeast part of Belchertown. These may have been derived from the deposit already described in Pelham; and yet I have not found blocks in the intermediate distance. In the east part of Barre, we find a distinct train: In the southwest part of Hubbardston, another: From the center of that place for a mile easterly, another: In the northeast part of the town, another: In Westminster, northwesterly from the meeting house, another. In all these cases the trains are too distinct, and the blocks too abundant, to permit us to doubt the existence of dikes beneath them. I have noticed only one other train of blocks, and that is in the northwest part of Royalston. Yet I am informed by my assistant, Mr. Abraham Jenkins, Jr., that trap dikes occur upon Mount Monadnac, in the south part of New Hampshire.

Dr. Percival, who has devoted himself most assiduously and successfully to this subject, informs me that he has traced a trap dike from Branford, on the shore of Long Island Sound, to the south part of Holland in Massachusetts. A little south of the line of Massachusetts it is seen in a ledge: and if we prolong a line connecting Branford and Holland, northeasterly, it will strike the trap in place in Fiskdale: and also that in the west part of Holden. I can hardly doubt, therefore, but this dike does extend at least as far as from Branford to Holden, a distance

not less than 90 miles. I shall expect to find that it may be traced far northeasterly into New Hampshire.

Another dike Dr. Percival has traced from the east part of Manchester in Connecticut to Monson in Massachusetts. I have not been able to find it in place near Monson on the north. But if we prolong a line connecting Manchester and Monson, northerly, we shall see that it passes near the region already pointed out in the east part of Palmer, and the south part of Ware, as strewed over with trap bowlders: and still farther to the north, it crosses the ledge of trap a mile south of the center of Phillipston. If we prolong this line into New Hampshire, it will not pass much to the east of Mount Monadnac, where, according to Mr. Jenkins, a greenstone dike exists 3 or 4 feet wide, extending nearly from the top to the bottom of the mountain. This runs nearly east and west; and simply indicates that there may be more extensive masses of trap in the vicinity. If we suppose the dike under consideration to extend from Manchester in Connecticut, to Monadnac, it would be 90 miles long. But if it extends only to Phillipston, it would be 65 miles in length.

It will be seen, that if we suppose the two dikes traced by Dr. Percival in Connecticut, to extend across Massachusetts, they will embrace but a few of the deposits of greenstone, connected with the gneiss, which are laid down upon the map. Some of these may perhaps be connected together; as probably belonging to the same dike. Thus, the mass in Montague, and the most easterly one in Pelham, may be connected; and may have furnished the train of blocks in the northeast part of Belchertown; and which I have met as far south as the rail road in the south part of Palmer.

If it be admitted that the trap of the gneiss region of Worcester county, does form continuous masses, as has been suggested, then, since the different dikes are not parallel to one another, they cannot run parallel to the strike of the strata of gneiss; as was probably the case with the greenstone of the Connecticut valley. In the limited deposits of this rock which I have examined in Massachusetts, I have seen no evidence that the strata of gneiss are cut across. But the opportunity for ascertaining this point is very poor.

I have no doubt but a more careful examination of the region under consideration, will bring to light many more examples of this rock, both in place and in blocks; and thus many localities now insulated, will be found to be connected. But this examination should be made on foot; so that the geologist can follow up his discoveries unincumbered by horse and carriage. Want of time has prevented me from taking this course as often as I wished.

Nos. 2333 to 2339, present examples of the trap rock that has now been described. It will be seen that there is far less variety than in similar rock connected with newer deposits.

### *Situation of the Greenstone of Massachusetts in relation to other Rocks.*

This subject has been necessarily somewhat anticipated. But a more particular statement of facts concerning it seems desirable. Our unstratified rocks occur in three modes: first, as protruding irregular masses: secondly, as overlying masses; and thirdly, as veins. The first and last modes are most common.

Since most of the greenstone in the eastern part of the State is not connected with stratified rocks, it must be referred to the first of these modes; except where it forms veins in the other unstratified rocks. I have never been able to find a satisfactory example, in which the greenstone distinctly overlies either porphyry, sienite, or granite;* although in numerous instances I have found a gradual passage from this rock into the two latter. But this is as likely to take place laterally as in a vertical direction. Examples of this gradual transition between these rocks are common south of the Blue Hills, as in Randolph, Stoughton, &c.

* Professor Webster says that it overlies compact feldspar in Charlestown. (Boston Journal of Philosophy, Vol. I. p. 282.)

Wherever I have seen this rock associated with the graywacke and argillaceous slate in the eastern part of the State, it either occupies veins, or protrudes itself in some other form, among, or between the strata. Professor Webster, however, says, that it is sometimes superincumbent upon the clay slate in Charlestown. (*Boston Journal Philosophy, Vol. I. p.* 285.) It has there also the appearance of being regularly interstratified with the slate. But I am satisfied that this is a deception; that is to say, these supposed beds are connected with some unstratified masses. Yet I think it extremely probable that some of the greenstone in the vicinity of Boston has resulted from the fusion of clay slate; and perhaps it is possible that a particular portion of the slate might be converted into greenstone, while that around it might remain but little changed; and in such a case, the rock might at the surface appear interstratified with the slate. In such a case, however, we should rather expect that the slate would be converted into hornblende slate: and Professor Webster says that some of the clay slate in Charlestown does pass into hornblende slate: and I would remark that much of the greenstone in the vicinity of Boston resembles exceedingly that variety of hornblende rock which is associated with hornblende slate: But for the most part it appears to have been subject to so entire a fusion that the slaty and stratified structure is lost; and hence it seems most proper to describe it as unstratified greenstone: although if it be true that all greenstone results from the same source as hornblende slate, it may be difficult in some cases to distinguish between them.

Professor Webster in his account of the geology of the region around Boston, states that the veins of greenstone in the graywacke conglomerate of that vicinity, run about 10° W. of South, and 10° E. of North. All such veins are probably of nearly cotemporary origin: their parallelism being explicable only on the supposition of their having been produced by the same cause.

The promontory of Nahant presents an interesting exhibition of greenstone veins both in argillaceous slate and sienite. Only a small remnant of the slate is found upon this promontory: and this is intersected by so many and so large veins, that nearly one half of the surface is greenstone. And yet the layers of the slate appear to have been but little thrown out of their original position: for their dip and direction correspond essentially with those of the same rock in other places. In such cases it seems to me impossible that the slate should have been solid at the time the greenstone was intruded among it, unless we suppose it to have been cut through with numerous fissures: an occurrence which in the present case is hardly probable; since some of the veins are ten feet thick, and quite numerous: and I cannot conceive how mere desiccation should have produced such fissures. But I can conceive how melted matter may have been forced through unconsolidated clay, without disturbing it latterly but a short distance: and perhaps this was the mode in which the veins at Nahant were introduced. If so, it is probable that the consolidation of the slate, and even, its conversion into flinty slate, might have resulted from this intrusion.

There is one fact, however, that rather militates against such a supposition. We find there two sets of veins; one of which intersects the other; and penetrates the adjoining slate. We here trace distinctly three epochs of formation of the slate and greenstone. First the slate, secondly the veins that intersect it, thirdly, those veins that cross both the first named veins and the slate. As to the intervals between the production of these three varieties of rock, we can scarcely form a conjecture. The slate having been deposited originally from water, must have required a period of considerable length, previous to its consolidation: But the two sets of veins might have been introduced almost simultaneously; since this might have resulted from two paroxysmal efforts of the same eruptive force.

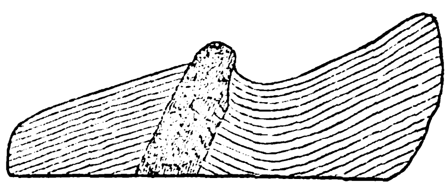
The greenstone occupying these veins at Nahant, varies in texture from the finest siliceous slate, to coarse sienite. The veins sometimes run parallel to the strata, and would be regarded by some geologists as regularly interstratified with the slate. And they would be confirmed in

this opinion by the apparently distinct stratification of one of the varieties of the greenstone on this promontory, particularly at a place about fifty rods northwest of the large hotel. The rock here is coarse and appears to be passing into sienite: It is divided into parallel portions by seams a few inches apart; and looking only to this spot, I do not see why the evidence of stratification is not almost complete. But if, as an almost universal fact, greenstone, sienite, and granite, are certainly not stratified, it is a presumptive evidence, that they never are so: Apparent exceptions it is reasonable to explain on other principles. And in the present case, there is a principle that may afford a solution of such a case as that mentioned above. I refer to the formation of concretions in the unstratified rocks. That they are frequently formed in all the varieties of these rocks, the records of geology will testify. Usually, however, they are only a few feet, or a few inches in diameter. But what reason can be adduced why they may not be produced of mountainous bulk? Their origin is, indeed, obscure: but probably their formation depends upon some modification of the laws of crystalization. And if so, who can tell through how large a mass of matter these laws may operate. In an example of apparent stratification in our granite, which I shall shortly describe, we have an opportunity of ascertaining that the layers are of a spheroidal form, although they cover a hill of no inconsiderable size. And in all cases which I have met with, it is only a part of the rock that is apparently stratified. This is the case at Nahant. There must then have been a peculiarity in the cause that could thus have affected one portion of the formation and not another. In some instances I have explained a partial and non-continuous stratification in rocks, (ex. gr. limestone and hornblende slate,) by supposing one part entirely, and the other only partially melted. But in the rocks under consideration, the division of the pseudo-strata is too distinct to admit of such an explanation: while the schistose structure is always wanting. Upon the whole, it seems to me that in the present state of our knowledge, sound philosophy requires that apparent stratification in rocks usually unstratified, should be regarded only as examples of a concretionary structure.

The geologist who may have occasion to spend several days at Nahant, will do well to give the spot a very thorough examination. I do not flatter myself that I have brought to light all the interesting facts which may be there developed; although I have exhibited enough to show it to be an interesting field for research.

The protrusion of the unstratified rocks through the stratified ones by internal igneous agency, now admitted by most geologists, has led observers to examine carefully for evidences of mechanical disturbance near the line of contact. They have, I believe, found less proof of such disturbance by the intrusion of greenstone, than in the case of the older rocks, as sienite and granite. Every such case, therefore, deserves to be noticed. If I mistake not, the following sketch of a vein of greenstone in argillaceous slate is an example of this sort. The dike is about 10 feet thick, and the general dip of the layers of slate in the quarry, is about 30° southeast. But as shown in the figure, near the greenstone the slate is considerably curved upwards in the contrary direction. The quarry, where this example occurs, is about half a mile north of the Powder House in Charlestown.

Fig. 139.



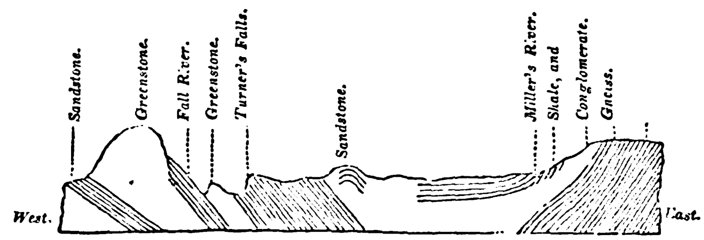
*Greenstone Dyke in Clay Slate; Charlestown.*

For the most part, the greenstone in the valley of the Connecticut is interposed in thick

masses between the strata of sandstone. I have never met with a mass of this rock of much extent, that was superincumbent in the sense of lying upon the edges of the sandstone strata. And yet the dip of the sandstone is often so small, that the greenstone seems to rest upon the face of the rock almost horizontally. The west part of the trap is usually precipitous, and the sandstone crops out beneath the mural front. But if we go to the opposite, that is, the east side of the ledge, we frequently find the sandstone lying above the greenstone, and in some places mounting upon it to a considerable height. The slope on the east side is also much more gradual than on the west side. I think, therefore, we must suppose, either that the greenstone was protruded to the surface between the layers of sandstone, or as I have suggested on page 526, that it was poured out upon the bottom of the ocean after the lower strata of sandstone were deposited. I know not how to explain the existence of the tufaceous conglomerate sometimes found upon the greenstone, without adopting the latter hypothesis. But on the other hand, where we find the sandstone with a decidedly larger dip above than beneath the trap, as in Belchertown and at Turner's Falls, it is difficult not to suppose that the protrusion of the trap elevated the sandstone. Perhaps we must adopt one theory for one locality, and the other theory for another.

At Turner's Falls, Connecticut river has disclosed, between Montague and Gill, an interesting section across the sandstone and greenstone, not less than 3 miles long. (Fig. 140.) It commences on the western side of the greenstone ridge against which Connecticut river impinges, a little below Turner's Falls, and by which its course is changed from northwest to south. At the western base of this ridge, the sandstone crops out beneath the greenstone, dipping 20° or 25° east. After passing easterly over this ridge, we find at the mouth of Fall River, another variety of the sandstone, mounting upon the greenstone at an angle of about 45°; that is, dipping easterly by that quantity, and running nearly north and south. Proceeding in the same direction, the sandstone continues only a few rods, perhaps 15, when we find it on the north shore of Connecticut river passing under another ridge of greenstone, 15 or 20 rods thick. On the east side of this second ridge, we find a similar variety of slaty sandstone dipping about 50° east. Several varieties of sandstone, some red, some gray, some fine grained, and some coarse grained, appear, as we pass along the same shore, with a dip between 40° and 50° east, for more than a mile. There we strike a somewhat more elevated ridge, which appears on both banks of the river, consisting of a brecciated indurated sandstone, described among the varieties of new red sandstone, whose strata are somewhat saddle shaped on the north shore, though quite indistinct. Beyond this point the shores for some distance are less bold, and no rock is visible for half a mile. When it again appears, the direction of the strata has become east and west, and the dip from 30° to 40° south. Hence only the horizontal edges of the strata can be shown on the section. But when we come within 100 rods of the mouth of Miller's river, the sandstone slate or shale is bent upwards, so as to dip westerly. Advancing towards the mouth of Miller's river, the westerly dip rapidly increases. Then for a considerable distance succeeds a coarse conglomerate, in which I could perceive no marks of stratification. For a few rods beyond this rock, diluvium hides the rock in place, and then, before reaching Miller's river, we strike a formation of granitic gneiss, hornblende slate, and mica slate, which constitute the western margin of the gneiss range of Worcester county. The strata of these rocks, at the mouth of Miller's river, and on the east bank of the Connecticut, (for we have now reached the spot where this river runs southerly,) run a little west of south and east of north, and dip to the west between 30° and 40°.

Fig. 140.




*Section between Montague and Gill.*

The above section is confined to the north shore of Connecticut river, from the west end until we reach the point where the strata begin to dip to the west. There it represents the south shore of the river. A more recent examination of the north shore, made it probable that the strata there do not dip to the west at all; and I am led to suspect that the westerly dip on the south shore, shown for a short distance on the section, may not in fact have resulted from the elevation of the primary strata in that direction. The truth is, the ranges of greenstone to which the sandstone in a good measure conforms, trend away northeasterly from Turner's Falls, and this is probably the reason why the sandstone strata along the central parts of the section, dip southerly. They form the northern extremity of a basin; and it may be, that the westerly dip of the shale on the east side of the section, may have resulted from original deposition upon a steep shore. In no other place in the valley of the Connecticut, have I found any evidence that the primary strata along its eastern border, have lifted up the sandstone; and hence the presumption is strong that such was not the case here. That part of the section requires to be carefully re-examined. But as the western part of it furnishes a fine example of the relative situation of the trap and the sandstone, I shall not withhold it. I think we have evidence in the decreasing dip, as we go eastward, that the trap has exerted an elevating force upon the sandstone: and the same fact appears in other places.

On the western slope of Mount Toby, in Sunderland, we find a narrow strip of greenstone interposed between the sandstone strata; as in the preceding section. Along the western and northwestern face of Mount Holyoke, we meet with the sandstone in several places, passing under the greenstone with a dip of 15° or 20°. On the opposite side of the mountain the strata are sometimes found elevated 50° and even 60°; as may be seen where the old stage road from Northampton to Belchertown crosses the greenstone ridge; and as we recede from this ridge, towards the east, or southeast, the dip diminishes. In the west face of Mount Tom, we find the sandstone passing under the greenstone at a dip from 15° to 20°: but on the east side of the mountain, it is no greater; and, therefore, I cannot say that this eminence has a wedge shaped form. South of Tom the sandstone both on the east and west sides of the greenstone ridge, has a less dip than in the cases above mentioned. Still, however, the greenstone seems to form a mass interposed between its strata.

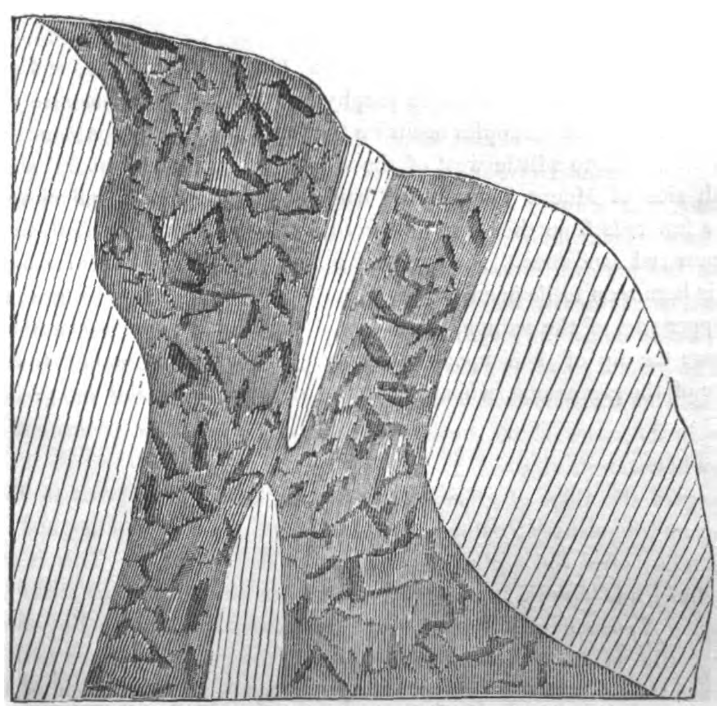
Are we to regard the ridge of greenstone extending from New Haven to Belchertown, as a vast dike, or as an irregular protruding mass? Its length is about 80 miles, and its average width not less than a mile: often the width extends to twice that distance. This is of enormous size to be called a dike: and besides, it generally conforms in direction to the strike of the sandstone. Yet after crossing Connecticut river, it apparently crosses the strata. But on examination, we find the strike of the sandstone conforming to that of the greenstone even here: and the latter still lies between the strata of the former; except perhaps near the east end of the ridge, where

the strata appear somewhat more confused. My views as to the probable manner in which this greenstone was produced, have been in part at least, already presented. I suppose that a fault runs through the valley of the Connecticut, and that after the deposition of the sandstone now lying beneath the greenstone, the trap was ejected through the fissured strata, and spread over the sandstone; which then probably lay nearly horizontal and beneath the ocean. Could we, therefore, penetrate deep enough, I presume we should find the greenstone existing in the form of a genuine dike. But as it now appears, it ought rather to be called a ridge, or even a bed, if it be proper to apply that term in any case to an unstratified rock.

## *Dikes of Greenstone.*

I have not met with any well characterized dikes of greenstone in the sandstone of Massachusetts: but they occur in Connecticut, as at East Haven. (*See a Section of some of them in the American Journal of Science, Vol.* 6. *p.* 200.) I have described on a preceding page, a few genuine dikes of this rock in the gneiss between the Connecticut and Worcester valleys. But it is in the eastern part of the State alone, that we find them in abundance. In the sienite and granite which abound there, the number of these veins is astonishing. They also extend into the stratified rocks on the borders of the unstratified. I shall defer an exhibition of any of these veins in the unstratified rocks till I describe sienite, that I may present them together; and in this place exhibit only Figs 141 and 142, which show some dikes of trap in mica slate in Lowell. They occur towards the west side of the city in a deep cut that has been made for a road, 40 or 50 rods south of the hotel called the Stone House. The height of the ledge shown on Fig. 141, is about 15 feet; and the narrowest part of the irregular dike is 6 feet. Near the middle of it two wedge shaped masses of slate from above and beneath, almost meet.

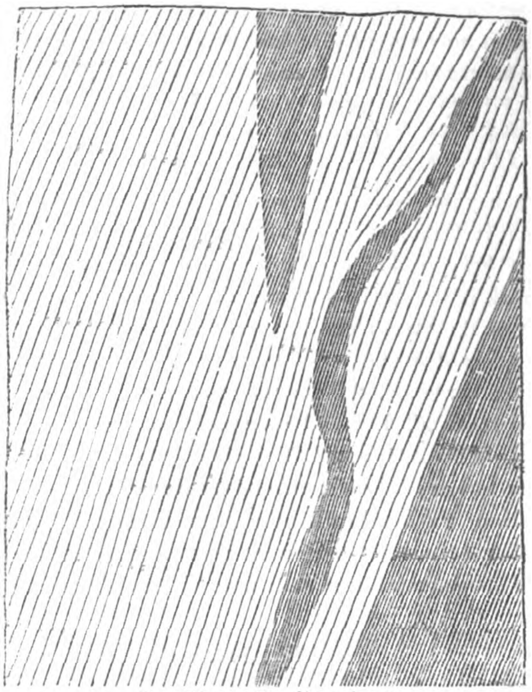
Fig. 141.



*Trap Dike in Mica Slate: Lowell*

Fig. 142 represents two much smaller dikes: one of which extends from the top of the ledge only a few feet downwards, and aparently terminates. Unfortunately the engraver (too late to be corrected,) has represented these veins as if slaty, and also the dark part on the right hand of the sketch, which is not trap but soil.

Fig. 142.

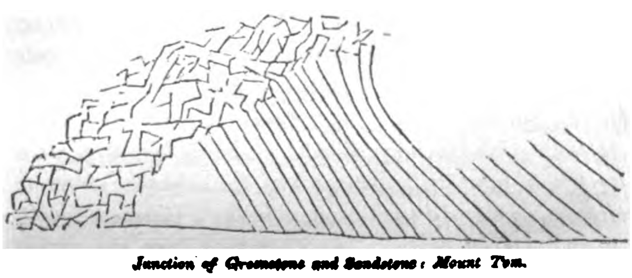


*Trap Dikes in Mica Slate: Lowell.*

The beautiful porphyritic greenstone of which No 1156 is an example, and some varieties of which, do not seem to differ from the black porphyry of the ancients, has rarely been met with by me in veins. The finest examples occur on the north shore of Cape Ann. At Sandy Bay I noticed dikes on the shore a little west of the village several feet wide.

On the south side of Mount Tom, on the bank of a small stream, and close by a saw-mill, which is only a few rods from the stage road from Northampton to Hartford, the following case occurs in the new red sandstone. A deposit of greenstone, the remains of a large vein or protruding mass, is here seen to lie in an oblique direction upon the elevated edges of the sandstone. Towards the upper part of the section, the layers of sandstone are curved considerably upwards, so as to increase the dip of their upper extremity. Must we not impute this flexure to the protrusive force of the greenstone, when first it was elevated to the day-light?

Fig. 143.



*Junction of Greenstone and Sandstone: Mount Tom.*

## *Chemical Effects of Greenstone upon other Rocks.*

In other parts of the world, it is a common case to find the rocks lying in contact with the greenstone, essentially changed in their characters, for a greater or less distance from the place of junction. This is most striking where limestone is the rock invaded by the trap. Similar effects are not wanting in the rocks of Massachusetts, that are traversed by greenstone. Yet it appears to me that they are hardly as common or striking as in some countries; judging from the descriptions of geologists. One reason may be, that greenstone here rarely comes in contact with limestone. The following are the principal examples of this agency with which I have met.

The influence of greenstone veins at Nahant, in converting argillaceous slate into flinty slate, and where carbonate of lime was present, into chert, has been fully described under graywacke.

Professor Webster describes a mass of trap, in Charlestown, as superincumbent upon a rock which he calls compact feldspar, 'which has many of the characters of clay slate, and in the immediate vicinity of the trap rock has a degree of hardness, a compact structure, and fracture almost like that of hornstone,—the slate seems to have undergone a great and remarkable change.' (*Boston Journal of Philosophy, Vol.* 1. *p.* 282.)

In the Connecticut valley the most striking chemical effects produced upon the sandstone by the greenstone, are induration, a vesicular structure, and change of color. In the 17th vol. of the Am. Journal of Science, Professor Silliman has described a most interesting example of all these effects, as they appear in a quarry, nearly a mile long, at Rocky Hill, about three miles south-west of Hartford. 'The trap is here superincumbent upon the sandstone, and this latter rock is changed to the depth of about four feet below the junction. Ascending from that depth, it begins to grow firmer; the color grows lighter, the red vanishes and it becomes dark gray—light gray—ash gray, and in some places almost white, while at the same time the firmness is much increased, so that from being a very soft and tender argillaceous sandstone, easily splitting into laminæ, it has become hard, and difficult to break, striking fire with steel like an overburnt brick, and its fissile character is almost or quite destroyed.'

'But this is not all. At the depth of about two feet, rather less than more, the altered sandstone begins to grow vesicular. Fine pin-hole cavities make their appearance; they are very numerous, and the solid substance which surrounds them becomes semi-vitreous and loses the appearance of sedimentary or fragmentary matter; as we ascend towards the trap, the vesicles increase rapidly in size, and at and near the junction they are both numerous and large.'

This vesicular structure is still more remarkable in the trap, extending several feet upwards; and near their junction, the two rocks can hardly be distinguished, and appear as if melted together.

Similar phenomena, more or less strongly marked, present themselves in other places both in Connecticut and Massachusetts, where the contact of the two rocks is visible. On the east side of Mt. Tom in Northampton, and on the south side of Holyoke, the vesicular character of the sandstone is most obvious: as is that also of the greenstone. (No. 286.) From the description that has been given of the relative position of these rocks in those places, it will be recollected that the sandstone is uppermost. The cavities are sometimes filled with some such mineral, as carbonate of lime, subsequently introduced; but the red color of the rock is generally retained: sometimes, however, it is not easy to distinguish this amygdaloidal sandstone from trap, without close inspection. Yet in most cases the line of junction is distinct, and the schistose structure of the sandstone is not lost. The greenstone, as already mentioned, is in these instances much more vesicular than the sandstone, and to an unknown depth. The cavernous base, the cavities not being usually

filled, differs but little from indurated clay; and some circumstances have led me to suspect that the rock in fact consists of argillaceous sandstone or shale, which has been fused.

A little below Turner's Falls on the Greenfield shore, the junction of these rocks may be advantageously examined, where they occupy the same relative position as above mentioned; that is, the sandstone is the superior rock. There it dips east from 40° to 50°: but I did not perceive in it any cavities; nor is the red color or the fissile character destroyed. Connecticut river here has worn away nearly all the sandstone, except an occasional patch, for one or two miles: but where these patches remain, a fine opportunity is afforded for observing the junction. And in some places I noticed that small rounded masses of the amygdaloid were partially entangled in the sandstone: as if, when the melted mass of greenstone was forcing its way upward, and pressing hard against the incumbent sandstone, portions of the former rock, while yet partially solidified, were worn off and rounded by the latter. More frequently we see fragments of the sandstone insulated in the greenstone.

For several feet below the surface of the amygdaloid at this locality, it is not uncommon to see that rock divided into parallel portions, whose surfaces correspond in dip and direction with the strata of sandstone. The thickness of these layers is from one to four feet. But they do not extend through the whole mass of rock, and can, therefore, hardly be considered as genuine strata

The existence of so much amygdaloidal greenstone on the eastern or upper side of the ridge, (for it must be recollected that such is the dip of the sandstone embracing the trap as to render the eastern the upper side,) while it is comparatively rare and far less porous and irregularly situated in the lower parts of the range, leads naturally to an inquiry as to the cause. It may be sufficient to say, that the gaseous matter extricated by the intense heat of a large mass of rock in a state of fusion, would naturally be forced to its upper part by the greater pressure below: although in the example described by Prof. Silliman, such does not appear to have been the case. Since, however, the base of the rock on the east side of the ranges above named, is more compact than that of the rock on the western or lower side, I am disposed to believe the former more favourable for retaining the gas or vapor than the latter.

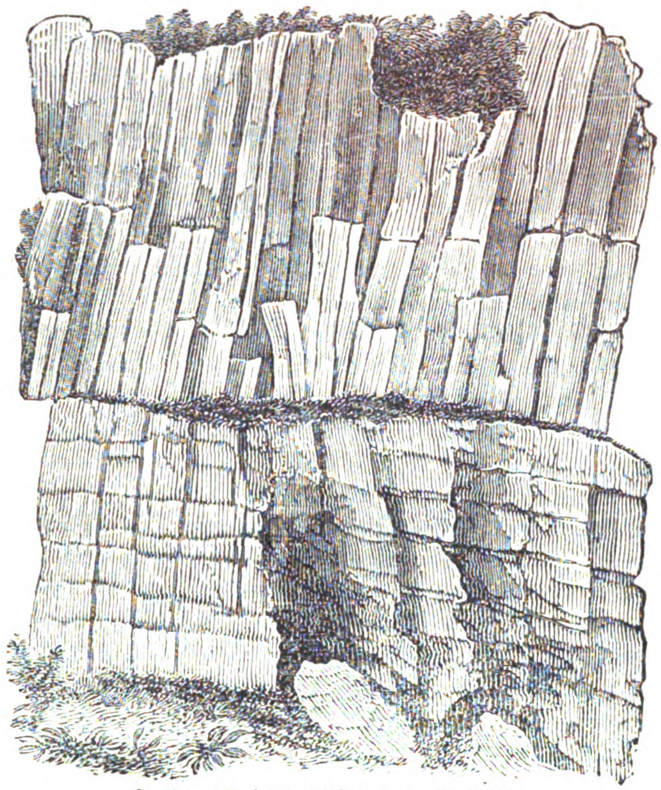
When the water is low we have an instructive exhibition of the junction of greenstone with the subjacent sandstone at Titan's Pier in South Hadley. A considerable part of the trap near the sandstone is a breccia; and one of the ingredients is clay, indurated almost to the hardness, and exhibiting the light gray color of hornstone, although not exactly that substance. This seems rather to have formed the paste in which are cemented dark pieces of trap. This rock extends but a short distance upwards from the line of junction.

The most interesting effects at this spot are exhibited, however, in the sandstone beneath the trap. Like that near Hartford, for two or three feet its schistose structure is in a great measure obliterated, although its stratification remains. It is also of a light gray color. On breaking it, it exhibits a semi-crystaline structure, bearing considerable resemblance to some varieties of fine grained granite. (No. 170.) But the most curious fact of all is, that this rock exhibits in some places a tendency to a columnar form. I cannot say, indeed, that any perfectly formed prism can be found. Still the sandstone exhibits several unequal sides of a prism, perpendicular to the planes of stratification, thus coinciding with the less perfect columnar structure of the greenstone immediately above: so that at a little distance one does not perceive the line of junction between the two rocks.

A more decided example of this columnar tendency in the sandstone, may be seen in the west face of Holyoke, a few rods north of Titan's Piazza. The trap here is more decidedly columnar than at Titan's Pier. Yet a person who was not a careful observer, would not readily distinguish the line of junction between this rock and the micaceous sandstone beneath. The latter is not, indeed, decidedly columnar, and the stratification may easily be traced. Still there are divisional

planes which extend perpendicularly through the sandstone, and are not the same as those divisional planes that sometimes give this rock a jointed structure. Fig. 144, will give some idea of this appearance. The spot is rather difficult of access, and somewhat concealed by brush and lichens.

Fig 144.



*Junction of Sandstone and Greenstone: Mt. Holyoke.*

That this columnar tendency of the sandstone is the effect of heat, can hardly be doubted, since Dr. Macculloch pointed out a similar effect upon the hearth stone of a blast furnace. (*System of Geology, Vol. I p 172.*) Many similar examples are now known in nature. (*Phillip's Treatise on Geology, Vol. II. p. 85.*)

Some of the sandstone of the new red sandstone is highly micaceous: this variety, where it occurs near the greenstone, can hardly be distinguished from mica slate. (Nos. 177 to 179.) I will refer only to two localities of this rock, viz. at Turner's Falls and at the north end of Mount Tom, at the spot where the sketch on page 421 exhibiting the junction of the two rocks, was taken. Can there be any doubt that these examples are in fact a partial conversion of the sandstone into mica slate by the heat of the greenstone?

I know of but one place in the valley of the Connecticut where greenstone comes in contact with limestone; and that is in West Springfield. Perhaps even there an actual contact does not exist, yet the greenstone is separated from the limestone in some places only by a narrow strip of sandstone. And a part of the limestone is more or less frequently converted into tripoli: that is to say, the carbonic acid is expelled, leaving the siliceous matter by itself. Probably this was the effect of heat: though I am not very confident that the tripoli was produced in this manner. A part of the limestone at that place is very much indurated, so as to possess almost the brittleness of glass when broken.

## *Mineral Contents.*

It is not unexpected, though gratifying to find in our greenstone many of the same minerals as occur in the trap rocks of Europe.

In describing the new red sandstone I have given an account of several veins in that rock of sulphate of baryta, native copper, and green carbonate of copper, with vitreous and pyritous copper. These veins often extend into the greenstone a considerable distance. But for the particular localities I would refer to the first part of my Report, p. 203.

According to the Messrs. Danas, (*Mineralogy and Geology of Boston, &c. p.* 66,) a vein of magnetic oxide of iron occurs in the greenstone at Woburn; though not extensive enough to render it an object for the miner. Intimately mixed with this ore is pyritous copper; and this last is invested sometimes with the muriate of copper. Quartz and amygdaloid at Brighton, and rolled pieces of granite at Medford, contain the same mineral. They state also that micaceous oxide of iron exists in the greenstone at Charlestown.

According to the same gentlemen, asbestus is found in fragments of greenstone in Brighton and Dedham; and I have found it in one of the anomalous varieties of this rock at Nahant. Probably, however, it is comparatively rare.

Epidote, as already mentioned, exists abundantly in the greenstone around Boston; but never to my knowledge in that in the Connecticut valley. Generally it is disseminated through the greenstone; but sometimes it occurs in veins, and is then usually compact, though often crystalized. At Breed's Hill is a locality: and a much better one at Nahant.

The cavities of the amygdaloid are sometimes occupied by a dull green foliated mineral which appears to be chlorite. The folia have in general a radiated structure, and sometimes invest calcareous spar. (No. 1173.) A little below Turner's Falls in Gill, just at the mouth of Fall River, on the east bank, is the best locality of this mineral with which I am acquainted. More frequently the cavities are occupied with earthy chlorite, and the specimens of this kind are very common along the eastern side of the ranges of greenstone in the Connecticut valley; as in Greenfield, Deerfield, South Hadley, Northampton, and West Springfield.

At the locality just referred to at the mouth of Fall River, occurs the rare mineral chlorophæite. It is abundant in the projecting mass of greenstone that appears at the junction of the Connecticut and the small river just mentioned; on the east bank of the latter; and the spot can hardly be mistaken by any one desirous of finding it. This mineral, when the rock is first broken, is of a dull green color: but after a few hours exposure it becomes nearly black. After long exposure, however, some specimens assume a dark brown color. For the most part the nodules,—often half an inch and sometimes more than an inch in diameter,—exhibit a fibrous structure, the fibres radiating from one or more centers in the same nodule. The mineral is easily scratched with a knife, and the powder is of a dull green color. When fractured, however, it appears brittle. Sometimes calcareous spar is enclosed within the chlorophæite; but very rarely are the nodules hollow. If I mistake not, in one or two instances I have observed a foliated structure in the specimens. There seems little danger of exhausting this locality. The same rock contains disseminated prehnite, chlorite, and pyritous copper. It is however, but slightly amygdaloidal.

Prehnite has been found in the greenstone in the vicinity of Boston, particularly in Charlestown. But it is more common in the valley of the Connecticut. Near the chlorophæite locality just described, on the Greenfield shore of the Connecticut, it is not uncommon in amygdaloid. There its color is nearly white. In general it is more common on the eastern side of the greenstone ridges, than on the western; for example, where Deerfield river cuts through a ridge of this kind in Deerfield, and on the east side of the same ridge four or five miles farther south, in a part

of the town called Pine Nook: also in West Springfield. But it is found likewise on the west side of these ridges; as at a spot one mile east of the village of Deerfield, and at another about the same distance nearly east of the village of Greenfield. The finest specimens that I have found in Massachusetts, occur in a ridge of trap rock that has been cut through in West Springfield by the Western Rail Road; a sketch of which spot is shown on Fig. 69. The balls of radiated prehnite here occupy veins in the rock, along with calcareous spar, which often invests the prehnite with minute crystals. Specimens will be found in the State Collection.

Augite of an iron black color and in imperfect crystals or in veins, is sometimes met with in the tufaceous greenstone of the Connecticut valley: as at a spot one mile east of the village of Deerfield.

Several varieties of the quartz family are found in the greenstone of Massachusetts; principally in that of the Connecticut valley. Limpid crystalized quartz is found frequently in the form of geodes, and sometimes these crystals are amethystine, of a delicate though not very deep color. This amethyst has been observed one mile east of the village in Deerfield; on the same range three miles south of this spot and east of the village of Bloody Brook; on Mount Holyoke; and in West Springfield. At the latter place the crystals are sometimes smoky. (No. 1117.)

The quartz that occupies the cavities of greenstone, as at a spot a mile east of the village in Deerfield, is sometimes tabular; and the folia are quite thin and delicate. Sometimes it is radiated, and not unfrequently it contains tabular or prismatic and radiating cavities, once occupied by a mineral. These cavities were perhaps once filled with Thomsonite; at least they resemble that mineral in form. I have seen them three or four inches in length, and crossing one another from different centers.

Chalcedony is not an uncommon mineral in the greenstone of the Connecticut valley. So far as I know, it is wanting in the greenstone around Boston: and this fact, with the almost entire absence of an amygdaloidal structure, are marks of peculiarity well worthy of notice. In the Connecticut valley the chalcedony is usually in small nodules, rarely more than one or two inches across. Most frequently its color is milky or smoky gray, and sometimes it appears to be real cacholong. At other times it is of a flesh color, from the lightest to the deepest shade, forming carnelian. Rarely it is yellowish, and closely allied to sardonyx. These varieties are most common in the greenstone range passing east of the villages of Greenfield and Deerfield, and on its western face; but rare on its eastern side.

All the above varieties of the quartz family are sometimes arranged concentrically, so as to form agates. Generally these are small: but some specimens found by Dr. Cooley in the south part of Deerfield, two miles northeasterly from Bloody Brook meeting house, were quite large. The largest of these specimens, nine by six inches in diameter and weighing 23 pounds, was composed of an outer zone of greenish chalcedony half an inch thick; and an inner zone of flesh colored chalcedony: the center consisted of an amethystine geode. The best of these specimens which I have been able to procure for the collection (No. 1191.) is about six inches by four: the outer zone is carnelian; the second bluish chalcedony, and the remainder limpid quartz, almost filling the cavity. When the outer coat is broken off, the specimen shows a strong resemblance to the human skull; exhibiting protuberances and depressions enough to satisfy the most sanguine phrenologist. Another specimen, three inches in diameter, exhibited no less than 14 concentric bands, consisting of various colors. This is a genuine *fortification agate*. Sometimes fortification and eyed agates are exhibited in the same specimen. It is to be feared, however, that this locality is nearly exhausted; at least, until a long period of time shall have decomposed the greenstone much deeper.

Calcareous spar is one of the most frequent of the minerals in the greenstone of Massachusetts; both in that in the eastern part of the State and in the Connecticut valley. Generally it

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is the laminated variety; sometimes flesh colored, but mostly limped. Often it constitutes the cement of trap tuff. Sometimes it is in distinct crystals.

A few years since, Prof. Silliman detected selenite in amygdaloid from Deerfield. It was white and retained its water of crystalization.

Several species of zeolitic minerals have been found in this rock in the Connecticut valley. Analcime has been frequently said to be quite common; but I am suspicious that calcareous spar has been confounded with that mineral: and I dare not say that it exists in our greenstone. Nor am I sure that laumonite occurs as far north as Massachusetts, although the greenstone in the vicinity of New Haven contains it. As to chabasie there is no doubt but it has been found in Deerfield, one mile east of the village. It is always crystalized, and almost invariably in the primary form, an obtuse rhomboid. The crystals vary from 1-50th to 1-4th of an inch on their sides; and these are grouped on tabular and pseudomorphous quartz, on prehnite, and on the greenstone: either in fissures, or more commonly in the cavities of the amygdaloid. This mineral seems to have entered these cavities for the most part at a later period than many of the others with which it is associated. For often we find it in the upper part of a cavity whose lower part is filled with another mineral; but never in a reverse order. The amygdaloid in which this mineral occurs is extremely hard, and hence the chabasie has been preserved. It is, however quite difficult to obtain good specimens.

In the amygdaloid on the east side of the greenstone range in Deerfield and Greenfield, I have observed a few rather poorly characterised radiated specimens, exceedingly resembling the Thomsonite of Scotland.

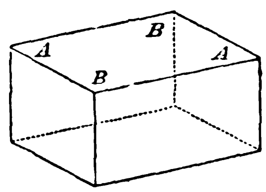
In the greenstone one mile east of the village in Deerfield, a mineral occurs, closely allied in external characters to stilbite and Heulandite: and formerly I described it as stilbite. But in its crystaline form it differs from both those species, and indeed from any known mineral. I have, therefore, ventured to describe it as new; and dedicated it to Governor Lincoln in my former Report, under the name of

### LINCOLNITE.

This mineral occurs in minute yet very distinct crystals, which are right oblique angled prisms. Three trials on as many crystals with the common goniometer, give the following results for the angles of the bases.

Fig. 145.

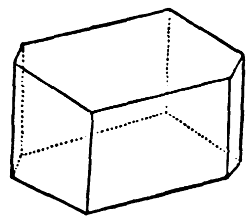
| | |
|---|---|
| First crystal: | Angles *A*, *A*, 61°. |
| | Angles *B*, *B*, 119°. |
| Second crystal: | Angles *A*, *A*, 61°. |
| | Angles *B*, *B*, 120°. |
| Third crystal: | Angles *A*, *A*, 61°. |
| | Angles *B*, *B*, 120°. |




The mean result of all the trials I have made does not vary much from 60° to 120°. But this may differ from the truth half a degree; I think not more. The bases are commonly bright enough for the application of the reflective goniometer: not so the lateral faces.

I have observed only one modification of this crystal, and that consists of a slight truncation on the acute lateral edges, as represented in Fig. 146. (No. 1202.)

Fig 146.



The height of the prism is about equal to the longest edge. It yields to mechanical division only parallel to the bases. It has a lustre somewhat pearly on the cleavage plane, and not unfrequently the folia are slightly curved. It is always white or colorless; sometimes transparent, but generally only translucent. In every other character it corresponds with Heulandite and stilbite. On hot coals it whitens, and before the blowpipe melts into a white spongy enamel.

The crystals of this mineral are mingled, usually in the least proportion, with crystals of chabasie; either in the amygdaloidal cavities of the greenstone, or in its fissures. I have rarely met with a crystal whose longest side exceeded the tenth of an inch: and most of the specimens in the collection will need a microscope for their examination. It is very rare and obtained with difficulty, though small specimens will reward the persevering collector. (Nos. 1200 to 1204.)

At the same spot in Deerfield a radiated mineral occurs, forming sometimes perfect spheres, of the size of an ounce bullet, which may be Lincolnite, though perhaps it is stilbite.

This same radiated mineral is found at Bellows' Falls in Vermont, encrusting gneiss. On examining some specimens which I obtained there a few years ago, I perceived several distinct crystals of Lincolnite, which are quite small: and I am more and more inclined to the opinion that the radiated mineral above spoken of, both at Bellows' Falls and at Deerfield, is Lincolnite.

It is obvious from the preceding description, that this mineral differs from stilbite and Heulandite, only in its crystalographical characters. Stilbite crystalizes in a right square prism. Heulandite comes nearer to Lincolnite; its primary form being a right oblique angled prism. But the angles of its bases are about 50° and 130°; differing 10° from those of Lincolnite. Such a difference cannot be imputed to the imperfection of mensuration; nor can I conceive how it could possibly result from any modification of stilbite or Heulandite. I cannot see, therefore, why the principles of mineralogy do not require that this mineral be regarded as a distinct species.

## 16. PORPHYRY.

The term porphyry in geology seems now to mean any rock in which "distinct crystals of one or more minerals are scattered through an earthy or compact base." (*Lyell's Elements of Geology, p.* 155.) In Massachusetts, however, although I have described several rocks as sometimes porphyritic, whose base is more or less compact, yet there is only one variety, and that limited to the eastern part of the State, that I regard as genuine porphyry.

## *Lithological Characters.*

1. *Compact Feldspar.* (Nos. 1206 to 1228.) This mineral, more or less changed by other substances chemically mixed with it, forms, I believe, the basis of all the porphyry in Massachusetts. At any rate, I have found no varieties, the base of which I was not able to fuse with a common blowpipe: and this fact, in connection with another, that the great mass of our porphyry has a base of well characterised compact feldspar, has satisfied me that this is the predominant ingredient in the whole of it. But this compact feldspar, both that which forms the paste of porphyry, and that which contains few or no feldspar crystals, varies exceedingly in color, in toughness, and in the ease with which it can be fused. And to what but an admixture with more or less of other minerals, can we impute these differences?

It seems to me, that in the present state of geological science, we may take it for granted, that compact feldspar has once been melted. But what was the original rock from which it was produced? Judging from the present constitution of the earth's crust, we must suppose that rock to have been one in which feldspar only predominated, but did not exist alone; or in some cases perhaps, the feldspar formed only a small proportion of the whole. The melting down of such rocks would produce just such varieties of compact feldspar as we find to exist. Sometimes they would be almost pure, while at other times they would contain so much silex, or other earth, that they could scarcely be distinguished from hornstone, jasper, quartz, &c.; and their fusion would be quite difficult.

Now it seems to me that there is too close a resemblance between this *a priori* reasoning and facts, to permit us to regard the former as mere hypothesis. It obviously gives us a clew to the whole history of compact feldspar, and prepares us to expect as great anomalies in its characters as can present themselves.

Compact feldspar in the vicinity of Boston forms deposits of considerable extent: I mean that variety which is so deficient in crystals of feldspar, that it would not generally be denominated porphyry. It is true, however, that a careful examination of this rock, will almost always detect these crystals in it; and sometimes polishing will bring to light a porphyritic structure where it was not previously obvious. Hence I have not hesitated to reckon compact feldspar as a variety of porphyry. The variety most wanting in feldspar crystals usually lies between genuine porphyry or sienite on the one side, and graywacke on the other. A deposit of it thus situated, extends from Medford to Malden. Another strip of it may be seen in the south part of Dorchester and Roxbury, and in the north part of Milton and Dedham. The same range, probably, appears and forms hills in Needham and Natick. It is most likely the other extremity of this range appears in Hingham. Often a portion of these deposits, especially on that side where they unite with graywacke, exhibits somewhat of a slaty structure; and when describing graywacke, I have mentioned a variety which is conglomerated compact feldspar. This was noticed near Neponset river, not far from the line between Milton and Dorchester.

Although the compact feldspar under consideration assumes almost every variety of color, yet there are certain predominant colors. One of the most common is a grayish white: as in Medford, where some of the rock has the aspect of granular quartz. This variety sometimes assumes a yellowish tinge, as in Newbury; and this appears to be one of the purest varieties of this rock, and the one which, if any, will answer for Turkey stones. (No. 1206.) A dark gray color is another that prevails; and sometimes it is obvious that the rock embraces fragments of indurated slate, not perfectly incorporated with the feldspar. A more striking and very common variety is red, of various shades, from brownish to blood red. The latter variety abounds in Hingham, where ledges of it may be seen a little north of the village. Specimens of this rock can hardly be distinguished from the jasper so called, of Saugus; and probably it is essentially the

same thing, viz. compact feldspar with a mixture of some other ingredients. Both of them are fusible with some difficulty into a semi-transparent porous glass. They correspond pretty nearly in their characters to the *rose petrosilex* of Sahlberg, described by Berthier in the 36th volume of the Annales de Chimie et de Physique, and which he regards as a distinct species from compact feldspar, and which Beudant has since described as such. However, it seems to me that if we make a distinct species o this variety, we must make a dozen others from the compact feldspar of Massachusetts. He would erect this into a new species, chiefly because it differs from feldspar so much in composition. But if compact feldspar had an igneous origin, should we not expect its composition to vary much according to the greater or less quantity of foreign substances that happened to melt and mix with the feldspar: nor would this be a reason for making distinct species, so long as the constituents of feldspar predominated. Some specimens of our compact feldspar of a reddish color exhibit traces of a schistose structure, and are traversed by thin veins and layers of quartz. These melt with great difficulty.

These are the principal varieties of color that I have met with in the non-porphyritic compact feldspar of Massachusetts. When porphyritic, however, it exhibits several other predominant colors, which will be mentioned in the proper place.

2. *Antique Porphyry.* (*Porphyre antique, Al. Brongniart.*) This variety constitutes the great mass of the porphyry in the vicinity of Boston: and I call it antique because it so closely resembles that used in the monuments and ornaments of the ancients. As to this point we have the testimony of Prof A. Brongniart, who quotes 'Chelsea near Boston;' as a locality of porphyry, and says that 'it entirely resembles the antique porphyry.' (*Classification des Roches, p.* 108.) He might have added that probably as many, if not the same varieties occur in the vicinity of Boston, as were employed by the ancients. The specimens which I have placed in the Collection, and the most of which are polished, will render this statement probable. For if I could obtain so many varieties during the little time that I have spent in examining this formation, how extensive a suit might be brought to light by long and careful research!

The compact feldspar that forms the base of these porphyries presents numerous varieties and shades of color. One of the most elegant, is a light green, such as occurs in Chelsea and Malden; (Nos. 1255, 1256, 1257,) or the deeper green that I have met with in Milton. (No. 1255.) Red of various shades is a still more frequent color. (Nos. 1247 to 1253.) A reddish brown is sometimes met with. (Nos. 1240, 1241, 1243, 1258.) A nearly black color more often: (Nos. 1234, 1235, 1236.) A gray color sometimes: (Nos. 1239, 1242, 1244,) and a purple color rather seldom. (Nos. 1232, 1233.) The imbedded crystals are usually of a light color, sometimes white, sometimes brown, and sometimes greenish. Generally they are foliated, very rarely compact, and distinguished from the base chiefly by the color.

3. *Porphyry with a base of compact Feldspar, and two or more minerals imbedded.* (Nos. 1258 to 1262.) Feldspar and quartz are the two minerals present: but I have noticed usually small plates of mica. Sometimes it is very obvious, indeed, that this rock is intermediate between sienite and porphyry. In other words, it seems to be the former rock partly melted down into the latter. The porphyry of the Blue Hills is chiefly made up of this variety; though some perfectly formed porphyry is found there. The quartz is usually hyaline and smoky, and sometimes it forms the only imbedded mineral; the feldspar being all compact. In such cases especially, where the base is of a light color, the rock exceedingly resembles trachytic porphyry; (Nos. 1261, 1262,) and it will hardly admit of being polished for ornamental purposes. That a porphyry, which, by being thus associated so intimately with sienite, is proved to be one of the oldest varieties on the globe, should so much resemble the most recent variety, proves that similar causes have operated in its production at different and very remote periods.

4. *Brecciated Porphyry.* I know not how to describe this variety better, than by saying that it is composed of angular fragments of porphyry and compact feldspar, re-united by a paste of the

same materials, which is itself also porphyritic. Hence it appears that there must have been an original formation of these rocks, (compact feldspar and porphyry,) which was subsequently broken up, either by the mechanical agency of water, or the mechanico-chemical agency of heat, redissolving and mingling the materials. The fragments are of various colors, usually, however, gray or red: and this proves that rocks from different localities must have been mixed together. The paste is commonly in the greatest quantity; and the rock is as hard and broken with as much difficulty as any other variety of porphyry. It is not a very common or abundant variety: but for ornamental purposes it affords specimens of great delicacy. (Nos. 1263 to 1270.)

## *Dendritic Impressions.*

Our porphyry sometimes contains very beautiful dendritic impressions, which are easily mistaken for vegetable relics. The Eastern Rail Road cut through this rock in Lynn, has brought to light the finest specimens. No. 2372, is an example; though by no means as good as many which have been found. No. 2373, is a specimen of the Saugus jasper with similar impressions: and No. 2374, a like example on hornstone, or compact feldspar, from Holliston. This mimic arborization results probably in all these cases, from the infiltration of an ore of manganese into very narrow fissures in the rock.

## *Topography of Porphyry.*

Only three ranges of this rock are given on the Map; and these are all in the eastern part of the State. Two of them,—the principal ones,—lie, the one on the north and the other on the south of Boston, having their longitudinal direction east and west. The third is in Essex County, extending easterly from Byfield Academy, nearly or quite to the coast. This strip is chiefly compact feldspar and mostly the red variety. It certainly deserves a more thorough examination than I have been able to give it.

In some places farther south, as for instance on the turnpike between Boston and Newburyport, in Topsfield, I observed a rock in place, intermediate between porphyry and greenstone: and not improbably genuine porphyry may be found in the vicinity.

This rock is most fully developed in its characters in the range a little north of Boston, extending from West Cambridge through Malden and Medford to the east part of Lynn, and thence with an interruption to Marblehead Neck, which is chiefly porphyry. The southern border of this strip, certainly towards its western extremity, is compact feldspar. The porphyry (mostly antique, though sometimes brecciated,) forms a broken ridge of considerable height, generally naked and precipitous on its southern side. On the north it is succeeded by sienite, and the two rocks are so closely connected that the line between them is very obscure and irregular. I am satisfied, however, that this porphyry range has been usually represented too wide. This is the range that will probably furnish the best varieties for ornamental purposes, whenever the public taste shall create a demand.

There is reason to suppose that this range extends much farther east beneath the ocean. For Hon. H. A. S. Dearborn informs me that Halfway Rock, lying in the ocean several miles east of Marblehead, is porphyry. Indeed, specimen No 1264 which he presented to me, will show that it is perhaps the finest brecciated porphyry in the State. Now as this island lies nearly in the direction of the Malden and Lynn porphyry range continued easterly, I infer that it did once reach so far; (and perhaps does now beneath the ocean;) nor can we say how much farther. We see here from whence proceeded the porphyry pebbles that are so common along the southern shore of Massachusetts Bay, and on the islands of Nantucket and Martha's Vineyard.

The porphyry range south of Boston occupies much more of the surface than that just described; and yet I doubt whether it contains so much genuine porphyry. It extends in a curvi-

linear direction from Medway and Medfield, following Charles river so as to enter Natick and Needham, thence turning easterly through Dedham, Milton, Braintree, and Quincy to Hingham. Yet it appears to be interrupted in Weymouth, and I have marked the deposit in Hingham as insulated. This is chiefly compact feldspar, especially the red variety. A branch from this range extends into the south part of Dedham. The range, it will be seen, embraces the greater part of the Blue Hills, the most elevated land in the vicinity of Boston, their highest point rising more than 700 feet above the ocean. But it is only the upper part of this mountain that is composed of porphyry, and by no means the whole of that: for sienite is frequently found there. The porphyry is chiefly that variety which has a trachytic aspect, being evidently intermediate between porphyry and sienite.

I have met with this sort of porphyry in no other places in the State, except one or two veins. Vein No. 2, ten feet wide in Cohassett, shown on Fig. 147, is feldspar porphyry, (No. 2340.) In the sienite of Whately I found a vein of compact feldspar two or three feet wide; but the foliated structure of the feldspar was not entirely obliterated. In the argillaceous slate of Guilford, Vt., a quite distinct porphyroid granite occurs, and with it well characterized greenish compact feldspar. These rocks are so obviously granite, imperfectly melted down, that I have thought it best to describe them under granite, and to place the specimens (Nos. 1467 to 1470) among those of granite. A specimen (No. 1211) of the Whately compact feldspar will be found in the Collection.

## *Geological Position.*

In respect to the relative position of the porphyry of Massachusetts, I have but little to say, because but few facts have fallen under my observation. I have never met with an instance in which this porphyry was exhibited in juxtaposition with any stratified rock; except as already remarked, the compact feldspar succeeds to the graywacke as an older rock and gradually passes into porphyry. This porphyry, however, is associated, both on the north and south of Boston, with sienite; and in all cases, so far as I have observed, *the porphyry lies above the sienite,* and there is a gradual transition between the two rocks. This fact is most obvious in the Blue Hill range, where one is often much perplexed to decide whether the rock be sienite or porphyry. The sienite in these cases, however, it is important to remark, is never so far as I know, that variety consisting of compact feldspar and hornblende, which occurs as a member of the overlying family of rocks, but that variety composed essentially of feldspar, quartz and hornblende, which is connected with granite. Hence I infer that our porphyry belongs to the oldest varieties of this rock that have been described.

## *Mineral Contents.*

Although in South America, according to Humboldt, porphyry forms the matrix of gold and some other metals, yet, in general this rock is remarkably destitute of foreign minerals. It is so in Massachusetts. In Malden, it contains a little specular oxide of iron, and this is the only mineral hitherto announced as occuring in it. A careful examination of specimen No. 1222 with a microscope, has led me to the belief that it contains a minute quantity of native gold. The

quantity is so very small that an assay cannot be made of it: yet it certainly bears an exact resemblance to native gold. The specimen is an extremely hard variety of compact feldspar approaching flinty slate, from the Blue Hills. I should not allude to this circumstance were not the porphyry of South America rich in this metal.

## 17. SIENITE.

Sienite, consists of a grantiform mixture of feldspar, hornblende, and quartz. And this definition I shall take as the type of the rock now to be described.

### *Lithological Characters.*

1. *Feldspar and Hornblende.* This differs from greenstone by the predominance of the feldspar: and yet it is obvious that in respect to many specimens, and even very large deposits, it is difficult to decide whether they should be referred to the former or to the latter rock. In almost all cases both the ingredients are more or less crystaline: though sometimes, as at Nahant, the feldspar seems to be passing to a compact state. The hornblende is almost universally black; the feldspar white, greenish, and yellowish. (Nos. 1271 to 1285.)

I apprehend that by a careful examination of the specimens of this variety, nearly all of them would be found to contain more or less quartz: but quartz and feldspar, when fine grained, seen through a microscope, resemble each other so much, that it is not easy to decide. At any rate, this variety insensibly admits quartz and mica into its composition, and thus approximates to granite. It is hardly necessary to say, that on the other hand it passes into greenstone. This variety, although elegant, is rarely wrought for ornamental purposes, on account of the proverbial toughness of the hornblende.

2. *Feldspar, Quartz, and Hornblende.* This variety embraces nearly all the sienite in the State that is employed for architectural purposes, including the quarries at Quincy and those on Cape Ann. Feldspar is the most abundant ingredient. This is foliated, and commonly of a grayish, bluish, or yellowish color. A hyaline quartz, varying in color from quite light to quite dark gray, is very uniformly mixed with the feldspar, so as to exhibit homogeneousness in the midst of variety. In general, the hornblende, which is black, is very sparingly disseminated, and hand specimens often contain not a particle. Indeed, over extensive tracts I have sometimes not met with any. Hence I have arranged under this variety a rock very common in the vicinity of Boston, differing from that just described only by the absence of hornblende. It is most common a considerable distance south of Boston in the counties of Norfolk and Plymouth. In some instances, as may be seen by the specimens, Nos. 1286 to 1308, the feldspar is flesh red, or a lilac red, and in others of a blood red color. Its great resemblance in structure and composition to the Quincy and Cape Ann sienites, and the remarkable absence of mica, have led me to associate it with the variety under consideration: and in fact it forms a part of the same range. I distinguish this rock from granite only by the absence of mica: yet it must be obvious that this mark is not very satisfactory.

Sometimes the feldspar in this compound of that mineral and quartz, is nearly or quite compact. I have observed this variety most frequently in the north part of Essex county, as in Rowley and Newbury. A like compound is connected with the sienite of other countries.

3. *Feldspar, Hornblende, Quartz, and Mica.* In this quaternary compound we have a still nearer approach to granite; and generally it passes into granite by the disappearance of hornblende and the increase of quartz and mica. Yet in all cases where I have noticed it, this rock occupies a position between genuine granite and the newer stratified rocks. Hence I infer, that geologically considered, the difference between it and granite are important to be noticed.

The feldspar and hornblende are the predominant ingredients in this variety. The quartz is in so small grains that it is apt to escape notice; and the mica being usually black, is very easily mistaken for hornblende. In general all the ingredients exhibit a liveliness of crystaline structure which is observable only in the oldest rocks. The feldspar is ordinarily white, sometimes flesh colored, and the hornblende black. The grain of the rock is commonly finer than that of the second variety. As yet it has been but seldom employed for architectural purposes; although it would be beautiful and enduring. (1319 to 1340.)

4. *Porphyritic Sienite.* (Nos. 1341 to 1349) I mean by this term any sienite through which are interspersed crystals or foliated masses of feldspar, so as to give the rock a porphyritic aspect. I do not recollect, however, ever having seen the last variety above described, porphyritic. And indeed, nearly all the rock which I regard as porphyritic sienite in Massachusetts, and specimens of which will be found in the collection, is almost entirely destitute of hornblende; and hence many geologists would regard it as porphyritic granite. But the specimens are rarely wanting in veins and disseminated masses of compact epidote, and I cannot but regard this mineral as more decidedly characteristic of our sienite than hornblende. If this be present and the mica almost or entirely absent, I have little hesitation in regarding the rock as geologically a part of a sienite deposit.

The most elegant variety of porphyritic sienite that I have met with in the State, occurs in Abington, and North Bridgwater, and in other parts of Plymouth county. Its base consists of quartz and feldspar, with an abundance of epidote disseminated and in veins. The feldspar crystals that constitute it a porphyry, are of a flesh color. There is also a dark colored mineral diffused through the mass, which may be hornblende or mica. This rock if polished would form, it seems to me, the most elegant ornamental stone in the State. (Nos. 1344 to 1347.)

The sienite of Cape Ann is often porphyritic. In one place, about half way between Sandy Bay and Gloucester Harbor, I found a variety in which the imbedded feldspar crystals are of a very rich bronze color, approaching in appearance to hypersthene. But when this rock is smoothed, its aspect is too dark to be elegant. (No. 1343.)

5. *Conglomerated Sienite.* (Nos. 1350 to 1353.) This is a most interesting variety on account of the bearing which its characters have upon the theory of the formation of sienite. I have met with it chiefly in the compound, No. 3, just described. The rock in general does not differ from that variety; but it contains rounded masses of the oldest stratified rocks. It is in fact a real conglomerate; and in some places the nodules are so numerous that it has very much the aspect of the coarse pudding stones of the newer rocks. The nodules vary in size from the diameter of half an inch to that of six or eight inches. They are not smoothed, like the pebbles in the more recent conglomerates, by mechanical attrition: but they appear like masses of rocks that have been partly melted down by heat. In almost all cases, hornblende predominates in these nodules: and often they consist of distinct hornblende slate. Sometimes they contain mica in considerable quantity, and more rarely they consist chiefly of quartz and mica, the former in excess, forming a kind of quartz rock. Feldspar is also frequently present, especially in those cases where the schistose structure is indistinct: and sometimes the nodule appears to be only a variety of sienite, in which the feldspar is in a smaller quantity than usual. Upon the whole, I think I have ascertained the presence of hornblende slate, mica slate, and quartz rock, in these nodules. When the rock is broken, they are knocked out without difficulty, like the pebbles from a common conglomerate.

The theoretical inferences deducible from these facts I shall reserve for the sequel.

6. *Augitic Sienite.* The presence of hornblende in this variety and the absence of mica, have led me to call it augitic sienite rather than augitic granite: although in position it is associated with granite. There are two varieties. The first is composed of black hornblende, greenish augite, and yellowish feldspar; all the ingredients except the feldspar exhibiting a very distinct

and lively crystaline structure. This variety occurs in the northern part of Belchertown. The other variety, which I have found only in bowlders in Amherst, consists of augite and feldspar; the former being so arranged in the latter as to present the appearance of letters. (Nos 1362, 1363)

## *Topography of Sienite.*

The eastern and northeastern parts of Massachusetts most abound in sienite. A large part of Essex county is based upon it, as are several towns in Middlesex. On the south of Boston it spreads over a large part of Norfolk county and some part of Plymouth. A glance at the Map will show where it prevails most extensively. In all these places it forms hills of moderate elevation with no very striking characters. Its particular situation in respect to greenstone and granite I have already described in treating of the former rock.

The only other place in the State where I have met with sienite in place, is in the valley of the Connecticut. Here I have marked two deposits of considerable extent. The first extends from Belchertown to Chicopee river: the other, on the west side of the Connecticut, occupies a considerable part of Northampton and Hatfield, and extends to the center of Whately.

Although sienite very much resembling that which exists in the valley of the Connecticut occurs in the eastern part of the State, yet none like that which is so commonly employed for architectural purposes in the eastern part of the State, known as the Quincy and Cape Ann sienite, is found in the valley of the Connecticut. Nor have I met with any in that valley which is porphyritic. Indeed, I have arranged nearly all which has come under my observation in that valley, under the quaternary compound described as the third variety in giving the mineralogical characters; although I doubt not but one or more of the four ingredients may sometimes be wanting. Perhaps all this sienite might properly be described as sienitic granite, or granite which takes a proportion of hornblende into its composition.

The sienite in the Connecticut valley occupies a low level, rarely rising into hills of more than 100 or 200 feet high. And on the west side of the river a considerable part of the formation is buried up by diluvium.

The sienite of this valley sometimes exhibits a tendency to assume a columnar form. Perhaps this is exhibited no where to better advantage than in the ledge by the road side about a mile north of Northampton village. The columnar masses are only a few inches in diameter, and are much less perfect than those found in greenstone. The fact, however is interesting, as indicating a similarity in the causes that produced the two rocks.

## *Pseudo-Stratification of Sienite.*

At one of the quarries of this rock at Sandy Bay, Cape Ann, on the road from thence to Squam, a remarkably fine example may be seen of the division of this rock into parallel layers. Their thickness varies from two inches to two feet, and great facility is thus afforded for quarrying the stone.

As this apparent stratification extends only a few rods, while all the rest of the sienite on the Cape that I have met with, is unstratified, we cannot regard this case as real stratification. I consider it an example of the concretionary structure on a large scale. But it is unnecessary in this place to dwell upon this explanation, since I have already discussed it in treating of a similar phenomenon in greenstone.

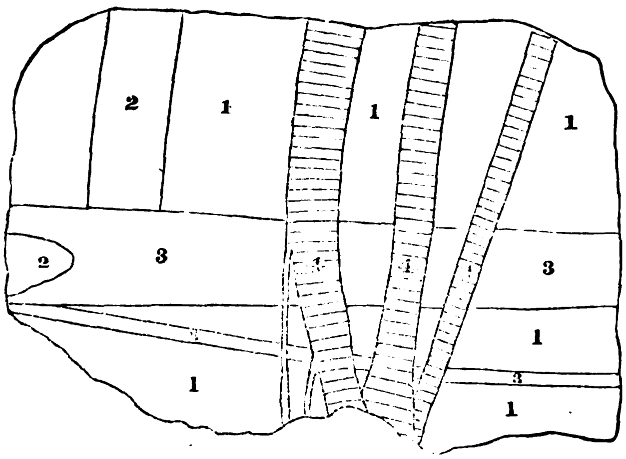
## *Veins and Dikes in Sienite.*

These are numerous and various in their probable mode of production, as well as in their composition. Some of them may properly be denominated , 'veins of segregation :' 'as they seem to have been formed by a separation of parts during the gradual passage of the mineral masses into a solid state.' (*Sedgwick* ) In most cases they appear to consist of harder portions of the rock, which become visible only by the weathering of the surface, when they are left in projecting ridges, and at a little distance cannot be distinguished from injected veins. I presume that it will be found in all cases, that these veins differ somewhat in composition from the rest of the rock and indeed, in some cases this is obvious, as they contain more or less of a foreign mineral, such as epidote or quartz.

No rock in Massachusetts contains as many veins and dikes as sienite. I shall first describe some of the most remarkable cases in the eastern part of the State.

South of Boston I have met with the best example of dikes, on the north shore of Cohasset. Fig. 147 shows a case at that spot, embracing a few square rods of surface. The basis rock, No. 1, is sienite. No. 2 is porphyry : (No. 2340) the principal dike being 10 feet wide, and the other spot, marked 2, being the end of a triangular mass of porphyry. No. 3 is greenstone ; the widest dike being 20 feet, and the narrowest but a few inches. (No. 2347.) This rock contains numerous small foliated masses of a bronze colored mineral, which exactly resembles bronzite. But it is as soft as talc, and I do not know its nature. This rock it will be seen, has cut off the porphyry dikes. No. 4 is marked on dikes of common greenstone, which are 8, 6, and 5 feet wide, and which intersect No. 3. In this case then, we have four successive epochs at which these rocks were erupted : 1, the original rock : 2, the porphyry : 3, the peculiar greenstone, No. 3 : 4, the common greenstone, No. 4.

Fig. 147.

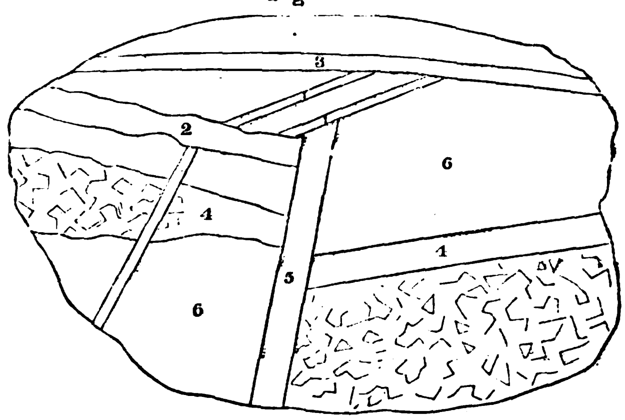



*Dikes in Sienite : Cohasset.*

It is in Essex county that we find the most abundant and remarkable examples of dikes and veins. The shores of Marblehead, Salem, and Beverly, and the numerous islands along that coast, are full of them. Fig. 148 will give some idea of the principal dikes upon Haste Island, in Salem Harbor. The island is only a few rods in extent, and is a naked rock of sienite, which is traversed by several distinct veins and dikes of granite and greenstone. Over a considerable part of the surface, it seems as if the greenstone in fragments had been thrown into the sienite while in a soft state, and then the whole had been consolidated. No. 6 is the basis rock. The

veins marked, No. 1, are probably the oldest. They are very narrow and of granite or feldspar chiefly. Nos. 2 and 3 are of white granite, and probably of the same age; the first being 4 feet wide and the latter 2 feet. No. 4, about 4 feet wide, is of greenstone, which at one extremity enlarges and seems a mixture of greenstone and sienite, and is younger than No. 5. The latter, of the same width, is also greenstone; and is the newest dike, unless it be a small vein of granite exhibited towards the right on the drawing, but not numbered, which crosses No. 4. We have then, at this place, rocks of at least five, and perhaps more epochs. The wind blew so violently, however, when I visited this spot, that I do not feel satisfied with the sketch below. I presume I may have neglected several smaller veins.

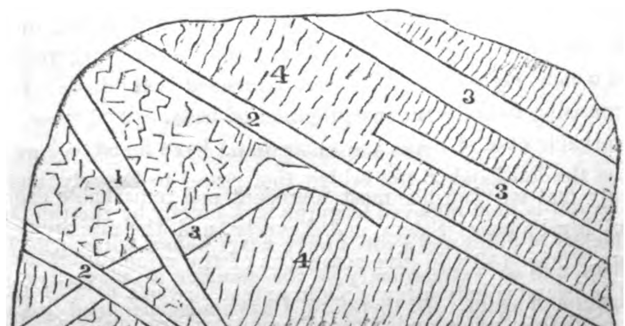
Fig. 148.




*Veins and Dikes on Haste Island: Salem Harbor.*

The rocky shore of Beverly, a mile or two east of the village, abounds with dikes and veins. The basis rock there is mostly sienite. But sometimes, if I mistake not, it is gneiss, passing into sienite: retaining enough of its original slaty structure to be recognized. In a rock of this description I took the sketch shown in Fig. 149. The dikes No. 3 consist of porphyritic greenstone; and one of them is cut off and thrown a good deal out of place. As the upper No. 3 is not affected by this movement, it may probably be of the same age as No. 2; which, however, is not porphyritic. No. 1 is a vein of granite: though most of the veins which I thus denominate are composed chiefly of feldspar. This spot is several rods long, and the veins, according to my recollection, are from one to four feet wide. But unfortunately I have mislaid my original sketch.

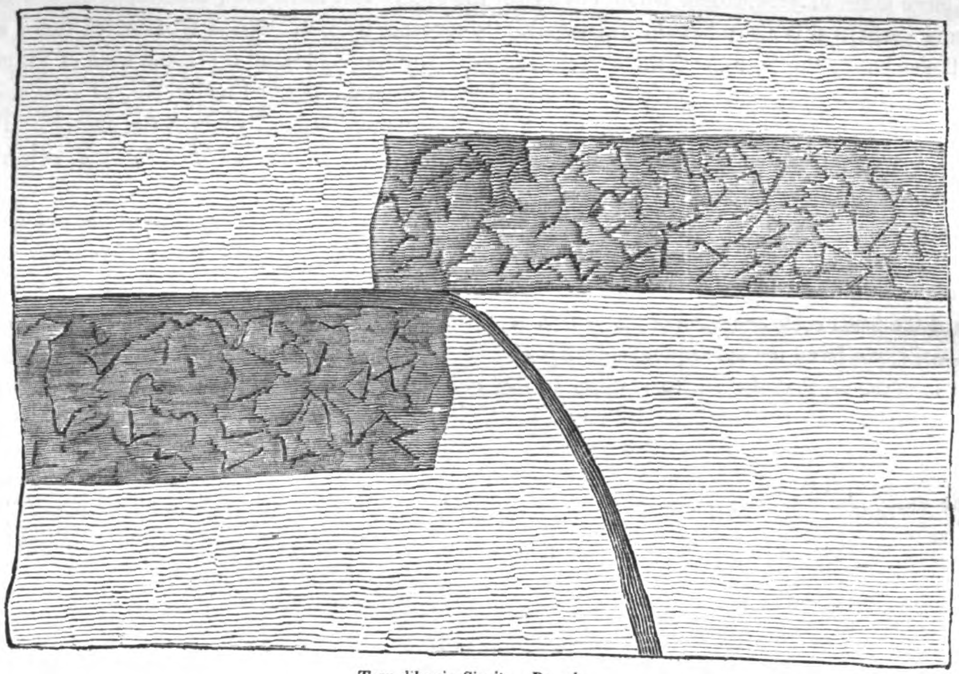
Fig. 149.




*Dikes in Metamorphic Gneiss: Beverly.*

Near the same place I noticed the peculiar example shown on Fig. 150. The basis rock is sienite, through which passes a dike of greenstone 2 feet wide, which has been broken off and one extremity crowded past the other. Between the extremities passes a second small crooked dike of greenstone. But notwithstanding all this disturbance, the sienite around the dikes shows no fissures which will explain the dislocation of the dikes. Indeed, the extremities of the dislocated dike are more firmly fastened to the sienite than I have ever seen before. The two rocks appear as if both had been partially melted and run together.

Fig. 150.



*Trap dikes in Sienite: Beverly.*

I know of no possible mode of explaining such a case as this, without supposing that after the large dike of greenstone was injected into the sienite, the latter must have been completely melted down, so as to admit of the dikes being fractured and the extremities slipped by each other; and then the melted matter must have filled all the interstices, and become chemically united to the greenstone. Many other facts that I have witnessed among our rocks, have impressed my mind with the same conclusion. Indeed, I believe we have yet much to learn respecting the manner in which veins and dikes were intruded and filled. And Essex county seems to me a most promising field for the investigation of facts.

By far the most remarkable case of dikes and veins that I have found, occurs in the north part of the city of Salem, on the left hand of the bridge that passes to Beverly, and only a few rods west of it. (Pl. 26.) The soil is here removed from the rock chiefly by the tide, two or three rods in width; and such a plexus of dikes and veins I have never before witnessed. So difficult is the work of unravelling them, and so extraordinary is the number of sucsessive injections, that I have visited the spot again and again. If, therefore, I have misunderstood this spot, it is not for the want of effort to understand its true history.

The oldest vein, or dike, (2) is greenstone, a few inches wide. Nos. 3 and 4 are veins of

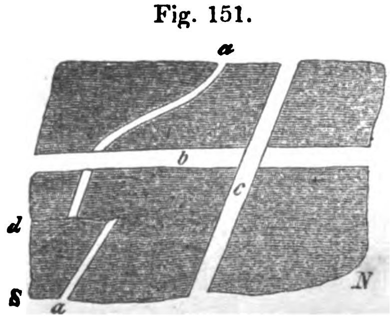
reddish granite,—nearly all feldspar, which cut across the greenstone dike No. 2. These are very numerous; much more so than is shown upon the drawing; and of very irregular width,—often branching out into strings a mere line in breadth. They belong to at least two epochs of eruption: for some of them are cut off by the others; and probably still more eruptive epochs might be traced among them: but they are so complicated that I have not been able to do it. No. 5 is a dike of greenstone, which cuts off 3 and 4. No. 6, which is 40 inches wide, is porphyritic greenstone, and cuts off No. 5. A small dike and nearly parallel, appears to be of the same age. No. 7 is porphyritic greenstone, cutting off No 6. No. 8, (of which there are two running nearly parallel,) intersects Nos. 5 and 7, and is granite or feldspar. No. 9 consists of two large dikes of greenstone, which cut off all the others that have been described, except No. 8; and perhaps this also: but the intersection is covered by soil. No. 10, of which there are small veins near the bottom of the sketch, and near the top, and is of the same kind of granite as Nos. 3 and 4, intersects nearly all the preceding veins and dikes. Finally, No. 11 consists of the same kind of granite veins, a mere line in width, running diagonally across the sketch. The whole space represented is 36 by 27 feet, and the lower part of it is covered by the ocean at high tide, and the upper part by soil.

I have spent a good deal of time in examining this complicated and very interesting net work of veins and dikes; and I cannot see why we have not evidence here of the extraordinary fact,—unique so far as I know,—of *eleven* successive eruptions of granite and trap rock. Or if we regard the basis rock as metamorphic—that is, formed by the fusion of gneiss,—and it may be so,—still, we have ten subsequent injections!

It is possible that the feldspar veins in this rock may be the result of segregation. Especially may this be true of Nos. 10 and 11, which are very narrow. But if we admit this, it leads to the extraordinary conclusion, that even after the nine preceding dikes and veins had been injected, the rock, including also the dikes which those veins cross, must have been in a state so fluid, as to allow the materials, to form granite necessary to separate from the mass. This seems to me more improbable than the only other supposition; which is, that all were injected veins.

I have already remarked that the sienite in the vicinity of Connecticut river approaches nearer to granite by taking mica into its composition, than that in the eastern part of the State. It abounds, however, in veins; which are always of granite, epidote, or quartz. In the granite, feldspar predominates, and mica is rare: so that the vein often becomes mere feldspar, generally of a flesh color. These veins, also, are usually so firmly united to the sienite as to seem like veins of segregation. The latter kind of veins do indeed abound in the sienite of Belchertown and Whately, as already mentioned; and it is not always easy to draw the line between them and injected veins. A granite vein is sometimes impregnated with epidote; but often the whole vein is epidote, generally compact, sometimes imperfectly crystalised. In such case they are very thin, rarely as thick as half an inch. Yet the slides that have often taken place in the fractured sienite, most frequently occur in connection with this sort of veins.

Fig. 151.




*Veins in Sienite: Whately.*

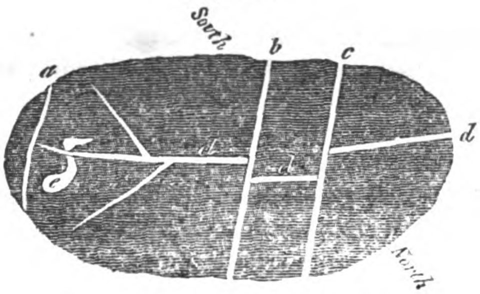
By far the most instructive exhibition of the veins that have just been described, occurs in Whately, a mile or two a little west of south from the congregational meeting house. I subjoin a few sketches of those that struck me as particularly interesting.

The above sketch, Fig. 151, represents an area about 10 feet long, and 6 feet wide. *aa*, is a fine grained granite vein, an inch wide at the upper end, and decreasing downward: *b*, another granite vein of fine grain, one foot wide: *c*, a similar one of equal width: *d* is a fissure, or rather an epidote vein.

*aa*, is obviously the oldest vein; for it is cut off by *b*, and this again by *c*. Hence we have here granite and sienite of *four* epochs: 1st, the rock of sienite itself: 2d, the vein *a*: 3d, the vein *b*, protruded subsequently: and 4th, the vein *c*, injected last of all. At what epoch the vein *d* cut off *aa*, we have no means of ascertaining; only that it was previous to the formation of the vein *c*, since this is not affected by the lateral slide apparent in *aa*.

The rock in the following sketch, Fig. 152, is about 15 feet long. *d*, *d*, *d*, is a vein of feldspar, two inches wide at its western extremity: but it ramifies at the other end and disappears. *a*, *b*, *c*, are veins of epidote, on each side of which the sienite has become indurated so as to present ridges on the surface of the rock an inch or two in width; the epidote being a mere line in thickness. These veins have cut off the feldspar vein and produced an echellon movement of the central part. *e*, is a nodule of some other rock enclosed in the sienite and cut off by the feldspar vein.

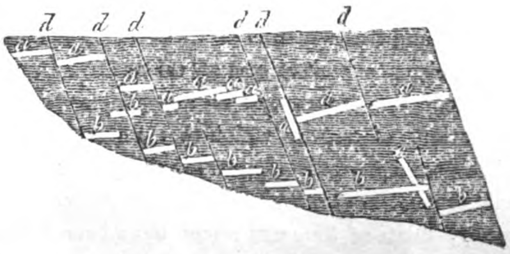
Fig. 152.




*Veins in Sienite: Whately.*

The following sketch, Fig. 153, exhibits a curious succession of echellon movements in the granite veins, *a*, *a*, &c. *b*, *b*, &c. produced by the epidote veins, *d*, *d*, &c. The sides of the rock represented are about 4, 6 and 10 feet. *c*, is a fragment of some stratified rock imbedded in the sienite and cut through by the vein *b*. The width of the granite veins varies from one to 2 1-2 inches.

Fig. 153.




*Veins in Sienite: Whately.*

It is easy to conceive how the detached portions of these two granite veins might be brought into *alignment*, (to continue the allusion above made to military manœuvres,) but how they could have been thrown into their present position, except when the rock was in a fluid state, I am

unable to conceive. And yet there must have been consistence enough in the veins to prevent their being diffused through the sienite. Does not this example lend some plausibility to the suggestion that the protrusion of veins took place while yet the rock was in a partially fluid state? Or must we, in order to explain such a case as the present, suppose a second fusion of the rock?

## *Position of Sienite in respect to other rocks.*

I am not aware that any of the sienite of Massachusetts can be properly called an *overlying* rock; that is, I have found no example where it lies above other rocks. On one side it usually lies next to granite, and on the other to greenstone and porphyry: or when these rocks are wanting, some of the stratified rocks, such as hornblende slate, graywacke, or new red sandstone, repose upon it. At least this is the impression I have received from all the examinations which I have made of our sienite. The low level at which it is placed, has caused it to be very much covered with diluvium, so as to hide its junction with other rocks. Yet in all cases where this rock occurs, we find it between the oldest granite and greenstone, or the earlier stratified rocks. Hence I infer that a portion of the materials of which granite is composed, under certain circumstances were converted into sienite, and that these circumstances existed generally in that portion of the melted granite nearest the newer stratified rocks. Or if we suppose it erupted at a different epoch from the granite, certain causes always forced it upwards between the granite and the newer rocks. Or if we suppose it to have resulted from the melting down of the stratified rocks, then perhaps their more or less perfect fusion produced the difference which we find between granite and sienite. But more of this last suggestion in the sequel.

## *Mineral Contents.*

The limits between sienite and granite, as well as between sienite and greenstone, are so vague and unsettled, that it is not always easy to ascertain to which of these rocks, minerals described by different writers belong; since in such a case geologists will be apt to give different names to the same rock. Genuine sienite, I mean that which is best characterised, is in Massachusetts rather barren of simple minerals: not quite so much so, however, as porphyry. By far the most common mineral is epidote; whose characters and mode of occurrence I have pointed out. The sienite used for architectural purposes from the vicinity of Boston, contains less of this mineral than any other variety in the State.

There is an interesting variety in the feldspar of this rock. In Beverly a few years since, a considerable quantity of green feldspar was obtained from a rock near the center of the place. And according to Prof. Shepard that rock contained small crystals of columbite and the oxyde of tin. (*Am. Journal of Science, Vol.* 34, *p.* 402.) The bronze colored feldspar of Cape Ann has been already described, and that which is of a lilac color in Hingham. In Charlestown a variety occurs in which the prisms exhibit stripes of various colors, and some have proposed for it the name *taenite* (No. 2455,) on account of its resemblance to a ribbon. On Holyoke and Tom I have described a variety of trap in which this mineral presents a similar appearance. According to Professor Webster, hypersthene occurs in the sienite of Hingham along with hornblende. Amethyst is said to exist in the same rock in that place.

In the sienite of Beverly, fluate of lime and zircon have been found; and the former mineral in rolled masses of this rock in Seekonk. In that of Charlestown, Prof. Nuttall discovered arragonite. Prehnite, of superior excellence, is found there in the sienite (Nos. 2458 to 2460.) and Prof. Webster, has recently informed me, that he has discovered in the same rock superior specimens of chabasie and laumonite.

'I have the satisfaction to state,' says Dr. C. T. Jackson, 'that I have found a vein in the sienite of Cambridge, consisting of calcareous spar, serpentine, prehnite, laumonite, and chabasie. The three last occur in very handsome specimens crystalised. The calcareous spar occurs crystalised generally in the form of dog-tooth spar. It is of a honey yellow color and is very brilliant.'

The veins of quartz abounding in delicate crystals in the sienite of Northampton and Whately, have been mentioned. Associated with these, I have sometimes found a mineral crystalised in four-sided prisms, which I have been disposed to refer to rutile. The best place for obtaining these minerals, particularly the quartz, is in Whately, about two and a half miles south of the meeting house. Some of the drusy surfaces of this quartz present a curious pseudomorphous appearance. (No. 1369.) It is precisely such an appearance as would result from making random cuts in the quartz, while in the state of a paste, with a thin bladed knife. Obviously it has proceeded from the infiltration of the quartz around some mineral in thin plates, originally occupying the cavities, and subsequently decomposing.

Following the eastern margin of this sienite about a mile south into Hatfield, from the locality just mentioned, we find a vein of sulphate of baryta, from one to four feet wide, running by the magnetic needle W. 22 1-2° N., and dipping about 90°. This baryta is the gangue of sulphuret of lead, blende, and pyritous copper. It has been excavated several feet, and the quantity of baryta thrown out was immense.

I have received from Sandy Bay, in Gloucester, Cape Ann, well characterised specimens of sulphuret of molybdenum. It is in plates in a vein of quartz running through sienite.

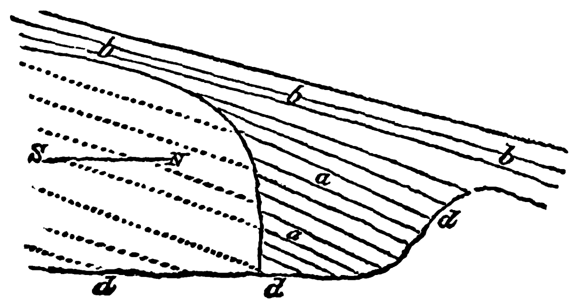
In the Dedham sienite a small vein of specular oxide of iron has been found. (No. 2456.) The nature of the rather remarkable ore disseminated in the sienite of Sharon. (No. 2404,) I have not found time to ascertain.

## *Theoretical Considerations.*

Sienite is very rarely found in Massachusetts in continuous veins in other rocks like granite and greenstone. Sometimes, however, as I have formerly stated, it penetrates sienite of a different variety, or greenstone, in so many directions and in such large quantity, that the rock so penetrated is divided into numerous fragments forming a kind of breccia, and appearing just as if the basis of the rock had been once melted, and had cooled with fragments of the other rock imbedded in it.

I have frequently observed the conglomerated variety of sienite in the eastern part of the State. But there the nodules are so much changed in their characters that they seem to be only a variety of sienite. It is in the valley of the Connecticut that the most interesting and striking facts on this subject are developed; and in that valley Whately is the place that most particularly claims attention. The following imperfect sketch will give an idea of the situation of the conglomerated sienite there. It is the northern point of a range extending through Hatfield and Northampton southerly: and it here abuts against a limited deposit of hornblende slate, whose strata run nearly N. E. and S. W. as *a, a,* Fig. 154, and stand nearly perpendicular to the horizon.

Fig. 154.




This slate is succeeded on the west by mica slate, *b*, *b*, *b*, which indeed, sometimes alternates with the hornblende slate. On the eastern side *d*, *d*, the sienite and the slate are covered by the diluvium and new red sandstone of the valley of the Connecticut. The sienite and hornblende slate are elevated not more than 100 or 200 feet above the general level of that valley: but directly west of these rocks the mica slate rises more rapidly into ridges of much greater elevation; forming the eastern margin of the broad range of Hoosac mountain.

Now I have been led by an examination of the spot just described, (whose length is 3 or 4 miles and breadth less than one,) to conclude that the sienite was formed by the melting down of the hornblende slate. I infer this chiefly from the fact that the former rock, as has been described, contains nodules of this slate, appearing as if rounded, not by mechanical attrition, but by heat. Why it should happen that the fusion of this slate should give rise to the production of feldspar, we may not be able fully to understand. And yet, if we suppose the hornblende slate to be composed of hornblende, mica and quartz, as it sometimes is in Whately, or that it alternates with mica slate, as it does there, we shall have in the materials melted down, all the essential ingredients of feldspar, viz silex, alumina, and potassa. A certain degree of heat may be all that is necessary to enable these elements to enter into the new combination that is necessary to the production of feldspar. At any rate, I think I am not mistaken in the fact, that as the imbedded nodules in the slate approach more nearly to sienite in their characters, and recede from those of slate, the greater the quantity of feldspar. What can this circumstance result from, but from the greater degree of heat to which such nodules have been subject? Their losing in so great a degree the slaty character proves that they have been more nearly melted.

Another circumstance lends in my opinion a plausibility to the preceding suggestions. Towards the northern extremity of the hornblende slate above described, and at least a mile distant from the sienite, we find the slate composed of compact feldspar and hornblende; and its schistose structure almost obliterated. There is also a tendency in the rock to divide into columnar and rhomboidal forms. Now in these facts we see, it seems to me, the effects of a heat sufficient to produce a partial fusion of the rock, but not an entire obliteration of the slaty structure: sufficient for the production of feldspar, but not for its crystalization. All this indicates a source of heat of great power at a small depth where probably genuine sienite exists.

There is another fact which I have noticed in one portion of this sienite, that lends still farther support to these views. Two miles south of the spot where the sienite and slate meet, I observed the traces of an obsolete stratification in the former rock, running in the same direction as the basset edges of the slate, indicated on the preceding sketch by dotted lines. There is no actual division of the sienite into parallel portions but only the marks of a former division by a sort of segregated ridges. The existence of the nodules of slate in the sienite proves that the fusion of the rock was never complete; and in these faint traces of original stratification do we

not see evidence of the same fact; and in the coincidence of direction between the strata of hornblende slate and these marks, have we not presumptive evidence of the origin that I have imputed to the sienite?

These various facts and inferences have led my own mind to make another inquiry. Do we not see here the reason why one part of a deposit is sienite, and another part granite; that is, destitute of hornblende? When the fusion of a rock is complete and the heat carried to a certain degree, may not the production of hornblende become impossible, because those affinities and polarites operate that produce other minerals, especially feldspar and mica? The sienite in the valley of the Connecticut at least, occupies a position generally between the granite and the newer stratified rocks. And if we suppose the heat to have been greater at the time of the production of these rocks, in proportion to the depth beneath the surface, it is obvious that it must have been greater where the granite was produced, than where the sienite is now found. For even if we do not suppose the sienite to have resulted from the fusion of stratified rocks, yet the proximity of its materials to these rocks must have greatly reduced the temperature of these materials: and if the stratified rocks were melted to form it, still more certain would such be the result.

This suggestion, as to the ground of difference between sienite and granite, derives some support from the great scarcity of crystalized minerals in the former, compared with those in the latter. I can imagine no cause for this difference so probable, as a more or less perfect fusion of the materials. The history of porphyry leads the mind to the same conclusion.

## 18. GRANITE.

Having included under sienite all those unstratified granitic compounds which contain hornblende as a constituent, the definition of granite becomes easy. It is, indeed, the common definition, which makes it to consist of quartz, feldspar and mica. Dr. Macculloch adds hornblende: but it seems to me that this destroys the usual distinction between granite and sienite. Granite may, indeed, contain disseminated crystals of hornblende, as of garnet, pinite, or any other mineral: but if the quantity of this hornblende is so great that it must be regarded as a regular constituent of the rock, I do not know why it should not take the name of sienite, unless we should merge all sienite in granite: and to this I have no strong objections. I can conceive, indeed, how the geological relation of granite with hornblende, may be such to granite without hornblende, that it would be preposterous to attempt to separate them: but I know of no such case in Massachusetts. Here sienite occupies, as we have seen, a constant geological position in respect to the granite about to be described.

### *Lithological Characters.*

1. *Common Granite.* This variety embraces nine tenths of the granite in Massachusetts. All those compounds of quartz, feldspar, and mica are included in it, which differ only in the size of the ingredients, in the greater or less perfection of their crystaline structure, and in their color. In these respects they do differ almost infinitely, as may be seen by the numerous specimens from various parts of the State in the Collection. (Nos. 1372 to 1461, and 2461 to 2479.) Generally the quartz is gray, sometimes smoky, sometimes blue, and sometimes yellow. The feldspar is or-

dinarily yellowish white; sometimes green, as in Southbridge; sometimes blue, as in Leverett; sometimes tinged with purple, as in Palmer; and more often flesh colored, as in the coarse granite found in Blanford, Westfield, Amherst, &c., and in the finer grained granite in the southeast part of the State. The mica is more commonly of a silver color; sometimes of a straw or gold yellow, or greenish; sometimes of a brown color; sometimes black; sometimes rose red; and sometimes it is prismatic, as in Russell and Norwich.

In magnitude the ingredients vary from that of masses one and even two feet in diameter, to those so small that they can be distinguished but with difficulty by the naked eye. Those granites that possess a fine grain are the only varieties that are employed for architectural purposes. The coarsest varieties are generally found in veins.

2. *Pseudomorphous Granite.* This is a variety that exhibits a structure so peculiar that I have thought it deserves a distinct notice. Suppose the quartz and feldspar requisite to form a coarse granite to be united into a solid mass. Suppose the mass to be now penetrated in various directions, by the blade of a thin knife, and the cavities thus produced to be filled by plates of mica not more than one fiftieth of an inch thick. Although these plates would form solid angles, they would not intersect one another; and so it is in the rock. The smallest fragment of the quartz and feldspar are often separated by the mica; but I have never seen one plate of that mineral intersect another. The solid angles which these plates form in the quartz and feldspar, however, appear like the projecting angles of crystals, and hence I have applied to this granite the term pseudomorphous. The mica is usually of a deep bronze color, and often the plates are four or five inches across. (No. 1462.)

3. *Porphyritic Granite.* (Nos. 1463 to 1470.) In this variety, besides the ingredients composing the mass of the rock, and which are quartz, feldspar, and mica, distinct imbedded crystals of feldspar are superadded. In Europe the basis of this rock is said to be fine grained: but in Massachusetts it is more commonly rather coarse grained.

Perhaps the most remarkable porphyritic granite in the State occurs in place in the west part of Harvard. (No. 1465.) It is a gray rather coarse granite with white feldspar, and the imbedded crystals are often two inches across; and being white, they give to the rock a striking appearance; and it has actually been mistaken by some writers for a conglomerate!

In Chester a large protruding mass of granite in the west part of the town is porphyritic. The imbedded crystals are much less than those just described, and of a gray color. The rock resembles porphyritic gneiss; but lacks both the laminar and stratified structure. (No. 1463.)

Probably a part of the rock which I have described as porphyritic sienite in the south east part of the State, as in Abington, North Bridgwater, &c. may more properly be regarded as granite. Indeed, as this rock is usually destitute of hornblende, perhaps the whole should be regarded as granite.

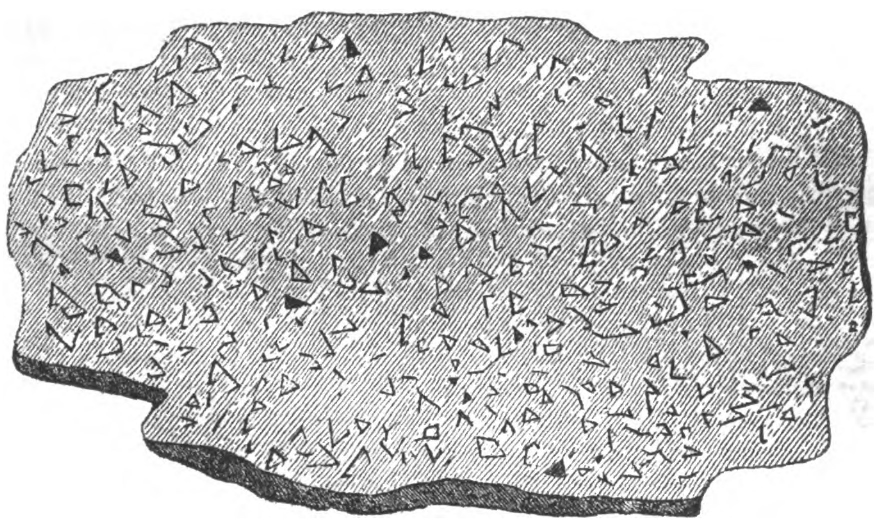
A very peculiar porphyritic granite occurs in the argillaceous slate of Guilford, Vt. just without the limits of Massachusetts I should have described this rock as a trachytic porphyry, were it not obviously a granite that has been partly fused. We can easily trace the gradations from the perfect granite to a rock composed of compact feldspar and imbedded masses of quartz. (Nos. 1467 to 1470.) At first we perceive nothing peculiar, except that the granite exhibits occasional spots of feldspar of nearly a milk white color, and a little indistinctness in the foliated structure of the feldspar. At length the feldspar becomes nearly all compact, and the mica, reduced in quantity, is disseminated in the mass as well as the quartz. Finally, the feldspar is perfectly compact and only grains of quartz appear in it. The rock now begins to assume a slaty structure, and seems in fact to be argillaceous slate that has undergone a kind of fusion The unchanged granite in this case is fine grained, and would form a beautiful stone for architectural purposes.

It may be seen by the specimen, No. 1455, that the granite from the quarries in Pelham, New Hampshire, exhibits a porphyroid aspect, similar to that just described. But I have not

visited the locality and cannot say whether all the circumstances above described exist in that place.

4. *Graphic Granite.* (Nos. 1471 to 1480.) In this variety, which consists of quartz and feldspar only, the ingredients are usually in lengthened prisms, so that the cross fracture presents the appearance of written characters. It is the Pegmatite of the French geologists. Dr. Macculloch thinks it occurs exclusively in veins. But that is not the case in this country, unless every protruding mass of granite be regarded as a vein. In the coarser varieties of our granite, a portion of the mass—generally a small proportion—is graphic: and there is no well marked line of distinction between the varieties. This is particularly the case in respect to the pseudomorphous granite, so common in Conway, Goshen, Williamsburgh, and Westhampton. In Goshen a few years since, I found a specimen which afforded so perfect an example of the graphic arrangement in this rock, that I thought it deserved to have its surface copied. (Fig. 155.)

Fig. 155.



*Fac Simile of Goshen Graphic Granite.*

## *Topography of Granite.*

Upon the present edition of the geological Map, it will be seen that I have represented considerably less granite than formerly. This is done chiefly because I am satisfied that much of our granite occurs only in the form of veins and protruding masses, among the stratified rocks; and in such a case, I think it better to represent the surface as occupied by the stratified rocks, when these do in fact predominate, and then describe them as abounding in granite.

To begin at the east part of the State: I formerly represented a belt of granite encircling Boston between the sienite and the gneiss. But I now regard that granite as subordinate to the gneiss. It exists in numerous veins and protruding masses, around which the gneiss, often converted into mica or hornblende slate, mantles. These masses are often of great size, and the texture is usually very coarse; as near the center of Andover, Billerica, Stow, &c. I do not doubt but a similar granite may be connected in some places with the sienite east of the gneiss. But generally I have found the coarsest varieties in the gneiss. I think the granite of the northern part of the gneiss range is decidedly the coarsest.

I have marked a deposit of granite, commencing at Little Compton in Rhode Island, thence extending northeasterly through Fall River, Freetown, a part of Middleborough, Carver, Kings-

ton, and Duxbury, until it passes into the sienite of Marshfield, Scituate, and Cohasset. At the two extremities, it most often shows itself at the surface. But from Freetown to Kingston, it is almost entirely concealed by diluvial sand. Its true limits, therefore, may be very imperfectly represented. But for this I see no remedy; unless I color the whole as diluvium. Almost every variety of granite occurs in this formation, from the coarsest to the finest. The latter, however, predominates; and at Fall River it affords some of the most beautiful stone for construction in the State.

On my former Map I colored a deposit of granite, connected on the north with that just described, and extending to Brewster on Cape Cod. I did this, because a ridge of considerable elevation extends down the Cape to Brewster, and many bowlders of granite are found of great size upon the hills. But re-examination renders it probable that the largest and most abundant of these bowlders are granitic gneiss, approaching so near to real granite, as easily to be mistaken for it: A somewhat similar rock occurs in place in Rochester and New Bedford; and my present impression is, that probably a ridge of this gneiss, and not granite, forms the axis of the Cape. But as the entire surface is diluvium, I thought it better to color it as such; thus representing what I know exists there, instead of something about which I am not certain.

The range of mica and clay slates passing through the valley of Worcester, and extending to the mouth of the Merrimack, abounds to the north of Worcester with protruding masses of a fine and beautiful granite, known in architecture as the Chelmsford granite. I have marked a strip extending from Harvard towards Westford, because I found it very abundant along that route; and near the slate quarries in Harvard it is particularly conspicuous. But although it is often seen in other places, to the north and northwest of Harvard, I have not attempted to mark it; because on so small a map nothing like a fair and full representation could be given. The deposit in the town of Worcester will be more particularly noticed on a subsequent page.

As we pass a little beyond this mica slate deposit westerly into Fitchburgh and Westminster, we meet with some quite large masses of granite. But I have marked none, except Rollstone Hill in Fitchburg, which is one of the finest examples of granite in the State, and in an economical point of view, would be invaluable were it nearer the sea board. This spot, however, I shall notice farther on.

The extensive deposit of gneiss between valleys of Worcester and the Connecticut, contains, with the exceptions just stated, but few examples of genuine granite; although much of the rock can hardly be distinguished, except by a practised eye, from granite. The granite is most common in the northern part of the range; and there the rock frequently passes into mica slate. As we approach Orange and Warwick, mica slate begins to predominate, and here we find protrusions of coarse granite; as in Erving, where one is marked. As we pass southerly along the western border of this gneiss range, we meet, in Leverett and Amherst, with a coarse granite in considerable quantity. Here too we find mica and hornblende slates.

As we go west of Connecticut river, we find similar rocks associated with granite. The large deposit marked on the Map as extending from Conway into Connecticut, is almost entirely connected with mica slate. This rock, indeed, often occupies the greater part of the surface; and the granite appears in veins and intruded masses. As we go westerly, the mica slate so decidedly predominates, that it is marked upon the Map. Still, the granite, which over this whole region, with a few exceptions, is very coarse, occasionally appears. Even as far west as the west part of Chester, a mass of porphyritic granite occurs, some miles in length, which might properly have been noticed upon the Map. But when we get far enough west to enter fairly upon the gneiss region, granite is far less common; and soon entirely disappears. Indeed, from all the facts that have come to my knowledge on this subject in Massachusetts, I cannot but suspect that mica slate instead of gneiss is almost uniformly associated with granite, because of some

metamorphic agency exerted by the latter rock. But as I have seen no suggestion of this sort from other regions, I merely throw out the idea.

In the whole of Berkshire county I have met with but a single deposit of granite, and that scarcely enters the state. It occurs in the west part of Clarksburg, and the associated rocks are quartz rock and an imperfectly foliated gneiss; or rather, the granite seems to pass into gneiss sometimes, though I have not marked the gneiss upon the Map. I presume that these rocks may be found more extended in Vermont; whither I have not found time to trace them. The great amount of the bowlders of this granite, that are strewed for 20 or 30 miles in a southeasterly direction, leads me to conclude the deposit to be more extensive than I found it in Massachusetts; though I doubt whether it is more than 10 or 15 miles long. The greatest peculiarity in this granite is its tendency to disintegration. The cause of this tendency does not exist in the feldspar, but in the other ingredients: nor can I conjecture which of them decomposes so easily.

With the exception of the deposit in Clarksburg, and some masses in Conway, Goshen, Chesterfield, Norwich, and Chester, the granite of Massachusetts appears only at a small elevation. And I have sometimes inquired, whether, if the whole surface were denuded as deep as that part occupied by granite, we should not find this rock spreading over a great part of the State.

## *Pseudo-Stratification of Granite.*

I have met with but two distinct examples of this peculiar structure in the State: but they are cases of peculiar interest. One occurs in the patch of granite marked in Worcester. It occupies the hill, 200 or 300 feet high, a little northeast of the village. The rock is composed almost entirely of gray quartz and white foliated feldspar, with very little mica, and hardly differs from the sienite of Cape Ann and Quincy; although entirely destitute of hornblende. It is quarried in various places on the sides and top of this hill, and in several of the excavations it exhibits a very distinct stratification. It is also crossed by numerous fissures, nearly perpendicular to the horizon, not having any uniform direction; and generally the apparent strata do not correspond on opposite sides of the fissures. This seems to result from their elevation or depression on the opposite sides. I satisfied myself, however, that the pseudo-strata conform on all sides nearly to the slope of the hill, being horizontal at the apex, and extending over the sides like the coats of an onion. If this be a fact, it shows conclusively that this hill of granite is an enormous concretion. The concentric layers, however, do not extend to every part of the hill: and this fact proves that there is no real stratification in the rock.

The other case is Rollstone Hill, in Fitchburg, a little south of the village. This hill is in the form of an ellipsoid; its longest diameter running north and south, and its height above the village being about 300 feet. Near the top, on the west side, the stratiform arrangement of the rock is very obvious; the divisional planes being nearly parallel: and yet an examination of the whole hill will show that the apparent strata mantle over and around it, and in some parts are wanting. I cannot doubt, therefore, but it is a magnificent example of the concreted structure. Both this hill and that in Worcester, appear as if they might have been protruded by internal heat, like an enormous vesicle; while the calorific influence, aided perhaps by galvanism, caused a division of the mass into concentric layers.

## *Phenomena of Veins and Irregular Protruding Masses of Granite.*

The only modes in which I have met with granite in Massachusetts are those of veins and protruding masses. In some instances regular masses with parallel planes are seen between the strata of other rocks; and on a superficial view, seem interstratified. But careful examination

has always shown me, that such masses either cross the strata in a slight degree, or contract and expand like veins : and seem indeed to be veins coinciding nearly with the strata of the contained rock in direction. I can hardly say that I have met with granite as an overlying rock, though a few cases exhibit this rock in a near approach to such a condition.

The veins of granite in Massachusetts penetrate only the older rocks; the clay slate being the latest in which they are found. All the older stratified rocks abound in them ; though in quartz rock I have rarely met with any. In gneiss they are common, especially in the gneiss range east of the Worcester County mica slate : also in the vicinity of New Bedford : and in the southern part of the gneiss range in Hampden and Berkshire Counties. Mica slate is penetrated by them and broken up by protruding masses of granite, at almost every step, in the granite range on the west of Northampton, particularly in the towns of Westfield, Blanford, Russell, Chester, Norwich, Williamsburgh, Westhampton, Goshen, Chesterfield, Whately, and Conway. In talcose slate they are very rare : in hornblende slate not common : in micaceous limestone sometimes met with : in serpentine I have never found one. In granite and sienite they are very abundant : and almost always the ingredients are much coarser than the granite or sienite that contains them.

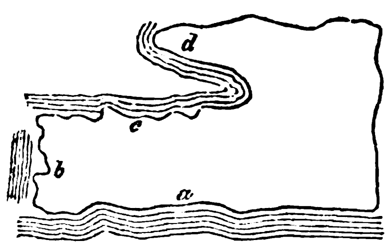
It ought to be premised, that in a large majority of cases, the intrusion of granite veins seems to have produced very little disturbance in the rocks containing them. They would seem to have been open fissures filled by the injection of granitic matter, without materially affecting the veins, except to unite with them chemically. And the same is true to some extent in regard to irregular masses of granite : that is, we do not always see any alteration in granite. Yet in such case we usually find not far distant, an irregularity in the position of the stratified rock.

In giving the details which follow, it will not be easy to state beforehand any definite order that will be adopted. The most that I shall attempt will be to bring into juxta position those cases that are analogous.

The sketch, Fig. 156, represents the manner in which the edges of the mica slate lie in contact with a protruding mass of granite in the south part of Conway.* At *a*, the slate runs north and south and dips east : at *b*, it dips south : at *c*, west : and at *d*, southeast. The sketch embraces an extent of only a few square rods.

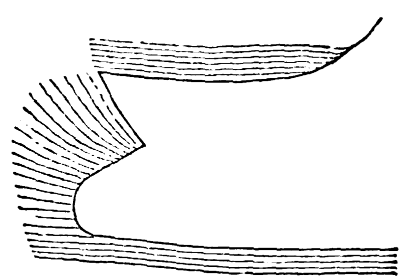
Fig. 157, exhibits a similar case near the village of Blanford, close by the road to Granville. The mica slate here runs nearly north and south, and dips 80° west : except at the end of the mass of granite, where the dip is nearly north, about 70° or 80°.

Fig. 156.




*Junction of Granite and Mica Slate : Conway.*

Fig. 157.

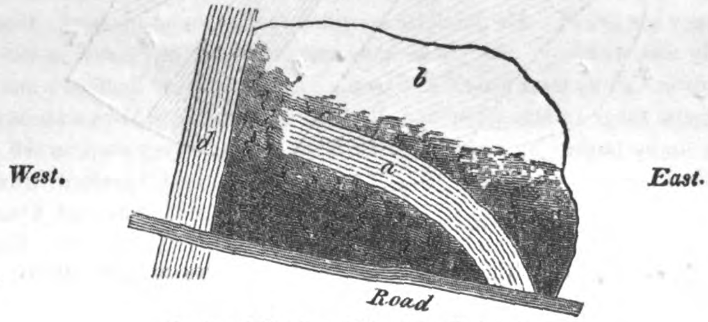


*Junction of Granite and Mica Slate : Blanford.*

* In nearly all the following cases the uncolored part of the sketch represents granite ; except that in a few cases irregular lines are drawn to represent the irregular divisions of granite.

The case on Fig. 158, I noticed in the west part of Leominster; where the numerous veins and masses of granite in the mica slate, and the great confusion obvious in the latter, made me desirous to spend more time in examining the surrounding region than I was able to do.

Fig. 158.

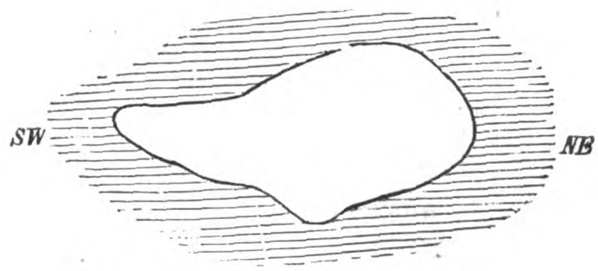



*Junction of Granite and Mica Slate: Westminster.*

At *b*, a mass of coarse granite occupies the top of a hill of considerable altitude. As we approach the road, descending from the hill, the granite is mostly concealed by the diluvium. At *a*, however, mica slate appears running nearly east and west. A few rods to the west at *d*, it runs nearly north and south; which is the usual direction of the slate in that region. What but the disturbing force of the granite could have turned the mass *a*, nearly 90 degrees?

Fig. 159, exhibits a protruding mass of coarse granite 20 or 30 rods long, in mica slate. The slate does not seem to be disturbed. It has an easterly dip of about 80°. The sketch was taken in the northwest part of Norwich.

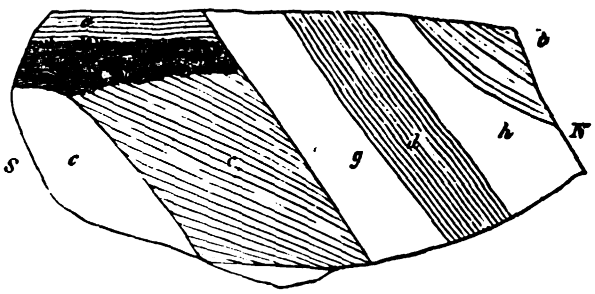
Fig. 159.




*Protruding Mass of Granite in Mica Slate: Norwich.*

The sketch on Fig. 160, was taken near the road from Norwich to Chester Village, a little after we begin to descend the high hill on which Norwich stands. Over many acres in that place the mica slate and granite are mixed in the greatest confusion: but I could sketch only limited patches, and of course it is scarcely possible to give a correct view of all the disturbance that has taken place. The sketch embraces a space about 8 rods long and 3 rods wide. *e*, *g*, *h*, are protruding masses or veins of granite. *a*, *b*, *c*, *d*, show the basset edges of mica slate. At *a*, its strata run nearly north and south, and dip rather less than 45° to the west: which is the usual dip and direction in the vicinity. At *b*, and *c*, the strata are turned so as to run nearly northeast and southwest; but the dip is increased only a few degrees. At *d*, they are still more wheeled, and the dip is as high as 60° or 70°.

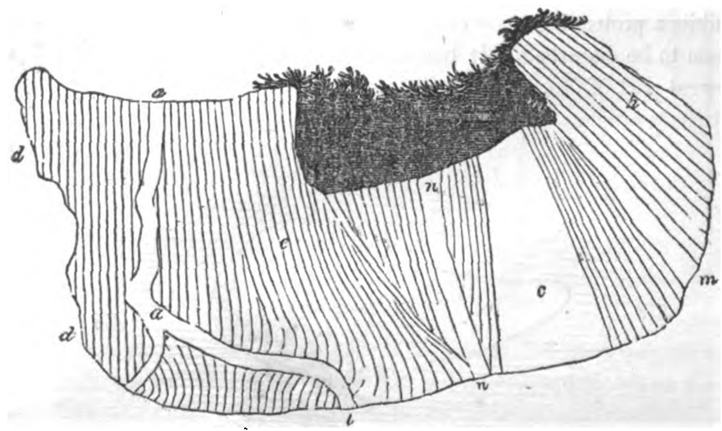
Fig. 160.




*Granite and Mica Slate: Norwich.*

The next case, Fig. 161, is at the same place, and embraces a space about 16 rods long. *a*, *a*, *b*, *n*, *n*, *m*, *m*, are veins of granite from one to two feet wide, and *c*, a mass 10 feet wide. A large mass also lies on the side *d*, *d*. At *h*, the mica slate is deflected only a few degrees from the usual strike of its strata, which is nearly north and south. The dip there is 45° north-west. But in every other part of the sketch, it will be seen that the mica slate is turned almost at right angles to its usual course, and towards the lower part of the sketch it exhibits most remarkable curvatures. The dip also, is in general greatly increased; so that in the vicinity of *e*, it is 80° north.

Fig. 161.



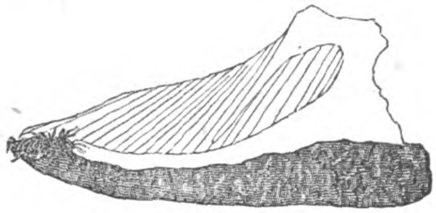

*Granite and Mica Slate: Norwich.*

I feel the inadequacy of such sketches to convey a just idea of the very great confusion which this spot exhibits. But if any one can examine such a place and still maintain that granite was not forced up through the slate while in a fused state, I can only say that his mind must be constituted very differently from mine.

The section, Fig. 162, was taken at the same place as the two preceding sketches. It shows an irregular vein or mass of granite protruding through layers of mica slate. The granite mass is only two or three feet wide, and the mica slate four feet. It is obvious that the upper portion of the slate has been forced upwards by the granite, so as to stand nearly perpendicular: the general dip being about 45° west.

In the northwest part of Norwich I sketched Fig. 163. Two beds or veins of granite are here shown: the central one, or that between the strips of mica slate, from 6 to 10 feet wide, and the outer one, which is but partly exhibited, 4 or 5 rods wide. One object I have in view, is to show

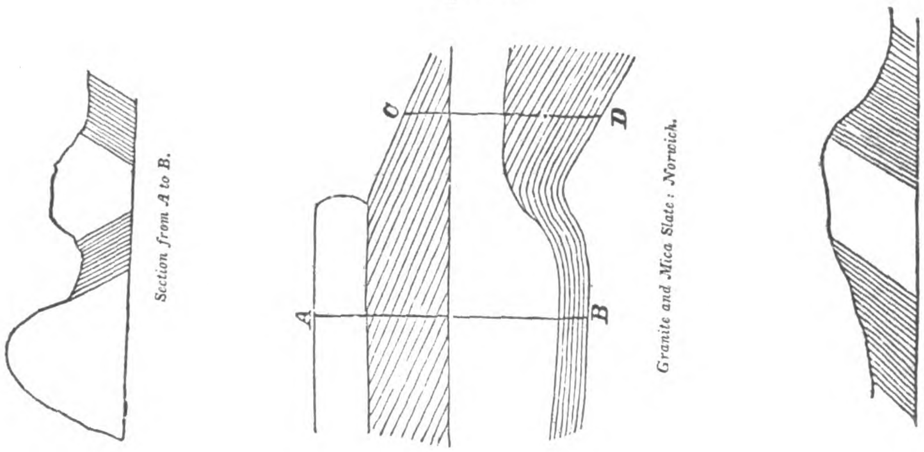
Fig. 162.



*Granite Vein in Mica Slate: Norwich.*

the curvature of the mica slate, where the central mass of granite expands. But the principal object is to show two sections across these rocks, four rods apart.

Fig. 163.

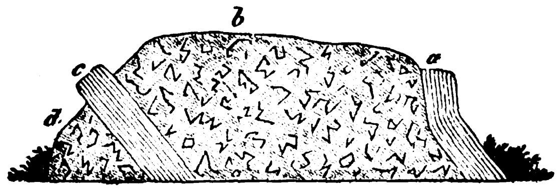



The change in the dip from 80° west, to 80° east, on the section from A to B, is striking; and is explicable alone on the supposition of a disturbing force exerted by these huge masses of granite.

The section on Fig. 164, crosses from west to east, a ridge of mica slate and granite, about four rods wide. The stratum *a*, at its lower part, dips easterly about 25° or 30°; which is the usual dip of the slate in the vicinity; but the upper part of this stratum is thrown up nearly perpendicular; resting against the granite This granite, *b*, is 3 or 4 rods across; when we find another stratum of the slate, *c*, having an easterly dip of nearly 50°. Below this another mass of granite, *d*, appears; but it is soon hid by the soil. Locality near the line between Conway and Williamsburg.

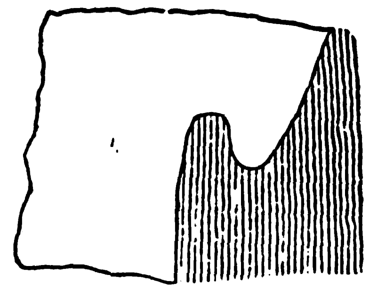
Fig. 165, is in the town of Russell, on the road from Westfield to Blanford. It represents a perpendicular ledge about 20 feet square, where mica slate and granite come in contact. The layers of the slate are perpendicular, and this rock is chemically united to the granite. It is easy to conceive how the two rocks should be thus wedged into each other, if we admit that the granite was erupted while in a melted state: but I am unable to imagine any combination or peculiarity of circumstances, by which such a case can be explained on the theory of the aqueous origin of granite.

Fig. 164.




*Granite and Mica Slate: Conway.*

Fig. 165.



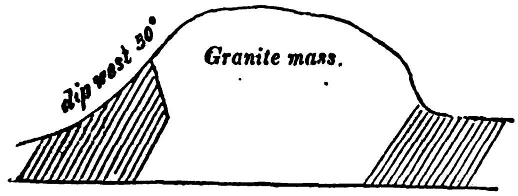
*Junction of Granite and Mica Slate: Russell.*

The sketch on Fig. 166, was taken, (not however with so much care as if I had intended it for this Report,) two miles north of Chester Village, in Chester. The granite mass is several rods wide, and the dip of the mica slate on each side of it, about 50 degrees west.

In the 8th Vol. of the American Journal of Science, Dr. Emmons has described an interesting case of overlying granite in Chester, with veins proceeding from it downwards. The mass is 5 rods in length. A somewhat similar case I have met in Carlisle.

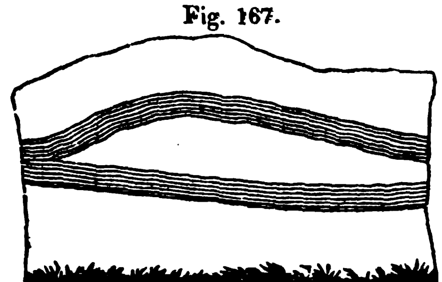
Fig. 167, exhibits the manner in which mica slate is sometimes insulated in granite. The spot here represented is several rods long, and occurs in Chesterfield, a little north of the meeting house. The dip and direction of the mica slate do not differ much from what is usual in the vicinity.

Fig. 166.




*Granite in Mica Slate: Chester.*

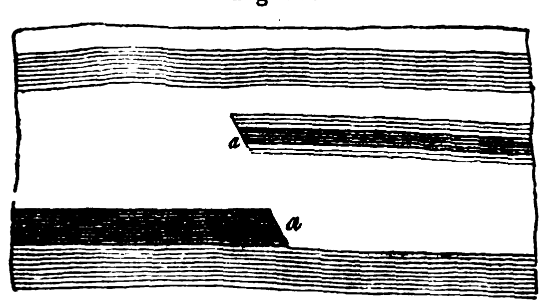
Fig. 167.



*Granite and Mica Slate: Chesterfield.*

The case, shown on Fig. 168, occurs about half a mile east of the meeting house in Williamsburgh. A granite vein about four feet wide, runs here in the direction of the strata of mica slate. The dark stratum, *a*, *a*, is hornblende slate, or perhaps amphibolic mica slate: and it appears to have been cut off and separated laterally a few feet. The upper mass of hornblende and mica slate is insulated in the granite, the narrowest vein of granite, however, being only three inches wide.

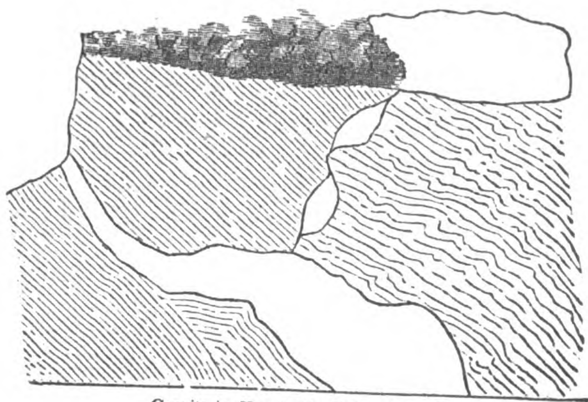
Fig. 168.




*Granite Vein in Mica and Hornblende Slate: Williamsburgh.*

Fig. 169, represents two irregular masses of granite connected by a vein, or rather by two tubercular masses of the same rock. They occur in hornblende slate, two miles northeast of West Granville meeting house, on the road to Blanford. The strata of this slate usually stand perpendicular. Where thus penetrated by granite, however, the dip varies from 70° to 90° west; and its layers are exceedingly contorted. Their usual direction, also, is very much altered in some parts of the sketch. The sketch embraces a space of several rods.

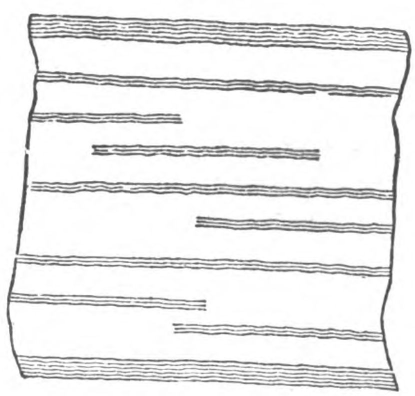
Fig. 169.



*Granite in Hornblende Slate: Granville.*

Fig. 170, exhibits a mass of granite three rods wide, with mica slate on each side, and embracing strips of mica slate from one half inch to six or eight inches wide. The direction of the layers in these insulated strips corresponds with that of the mica slate generally in the vicinity: viz. a north and south direction. This case occurs in Chesterfield, one mile east of the meeting house, on the road to Northampton.

Fig. 170.

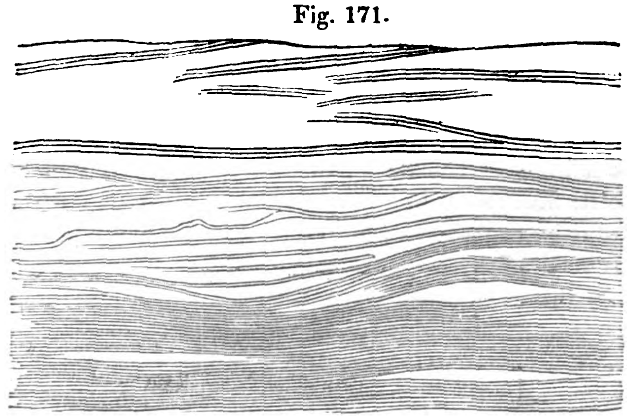


*Mica Slate in Granite: Chesterfield.*

Fig. 171, is a better representation of a similar situation of granite and mica slate, on the hill a few rods west of Great Falls in Russell. It shows the nearly perpendicular face of a ledge. At the bottom, the mica slate has the strike, dip, and character, usual in the vicinity. But as we examine the face of the ledge higher up, we begin to find double wedge shaped masses of coarse granite among the layers. These increase upward until the granite occupies most of the surface; and only thin layers of the slate are seen running through the granite. But their strike and dip correspond exactly with those in the slate below.

Cases of this kind are not uncommon along Westfield river and in the vicinity: and they seem to me to prove beyond all question, that the granite, in such cases, could not have been produced by injection. For even if it had been in the most perfectly fluid state, its intrusion among the layers of the slate, must have forced them out of their parallel position. Yet layers, hardly thicker than the blade of a knife, run through the granite, retaining the strike and dip of the slate generally, as exactly as if they had never been moved. It is difficult to convey by a mere wood cut an accurate idea of such a spot. But I am sure that an examination of the rock will satisfy any one that we must resort to some other theory for the production of the granite than intrusion. And if we could only suppose it the result of the melting down of the slate, it would meet all the facts satisfactorily. The chief difficulty in supposing such a transformation, is to find a source from whence the potassa of the feldspar in the granite could have been derived. But the facts that have been detailed on a former page concerning dolomitisation, prepare us to admit that perhaps potassa and even alumina may have been derived by sublimation from the interior of the earth. If granite might be supposed in some cases to have such an origin, it will explain more satisfactorily than any other theory, why we so often discover no marks of disturbance in the stratified rocks lying in contact with it.

Fig. 171.

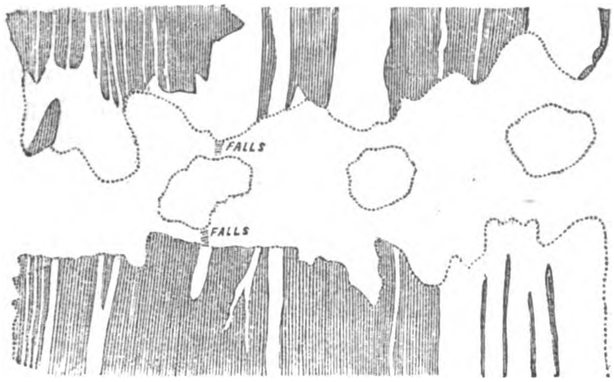


*Mica Slate, passing into Granite: Russell.*

The region about Great Falls, on Westfield river, is the Glen Tilt of Massachusetts. Nearly the whole bed of the river, which must be 6 or 8 rods wide, is occupied by an immense vein of granite, following the course of the river and crossing the strata of mica slate at right angles. Fig 172 will convey some idea of this spot. The parts not shaded represent the granite; and the dotted lines along each side of the principal unshaded strip, show the shores of the river at the time I took the sketch; while the spaces surrounded by dotted lines, represent small granite islands rising out of the water; one of which produces the falls which are shown on Plate 12. It will be seen that the principal vein sends out numerous smaller veins laterally, which almost universally are crowded between the folia of the slate, which dip northwesterly. Some of them are several feet in diameter; not less than 20. The whole length of the sketch cannot be less than from 20 to 30 rods; and I regret feeling myself obliged to give such a contracted view of this spot, which certainly should occupy at least one quarto plate.

At this spot we have, as it appears to me, an instructive exhibition of the manner in which granite veins are intruded between the layers of stratified rocks, and seem, where the central mass from which they originated is concealed, like regular interstratified beds. It is evident that they were forced between the strata, because the resistance was less in that direction than crosswise.

Fig. 172.




*Granite Veins in Mica Slate: Great Falls, Russell.*

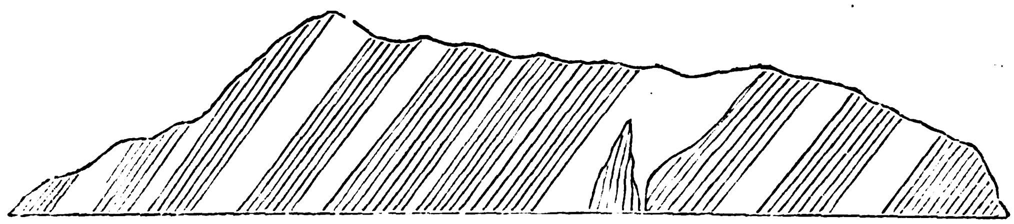
At Salmon Falls, several miles farther down the Westfield river, near the spot indeed where it passes out of its long gorge in the primary strata, the bed of the river exhibits an immense mass of granite, similar to that at Great Falls, and with slate upon its borders. I am inclined to believe that the same huge vein extends beneath the river, from one cataract to the other; and I fancy that this fact throws a gleam of light upon the manner in which this deep gorge across the primary strata was produced. The stream may, indeed, have worn out most of the valley, as I have suggested on a former page. But does not the existence of this vein prove that here was once a vast fissure in the strata, which was subsequently, in part at least, filled up by the granite? And did not the river run here because the rock was much more easily worn away, than where no such fissure existed, and also perhaps because it was not filled to the top? And may we not extend this same supposition to the gorge in the west branch of the Westfield river, even across the entire range of Hoosac mountain, along the route chosen for the Western Rail Road? If so, we might probably regard the gorge through which Deerfield river runs, and perhaps, also, that of Farmington river, as produced in a similar manner. In regard to Westfield river, I regard the alteration in the strike and dip of the strata at Chester village and in Russell, as shown upon Plate 53, as another indication that some powerful disturbance has taken place there.

If this inference be admitted, it furnishes us with an interesting example of the manner in which Divine Providence has provided prospectively for the comfort of man, by an act of violent dislocation of the earth's crust, which seems, upon a superficial view, to indicate rather a penal infliction. The deep gorges thus produced, and subsequently filled partially with detritus, become the channels of easy intercommunication in Alpine regions. It may be that the Western Rail Road, destined at no distant day to connect Boston, (and since the introduction of steam ships I might add the cities of Europe,) with St. Louis, and ultimately, perhaps, with the Pacific Ocean, may owe its existence to a violent disruption of the strata across Hoosac Mountain, while yet the earth was in a desolate and uninhabited state.

As has been shown above, numerous veins or intruded masses of granite extend among the strata of mica slate at Great Falls, on both sides of the river, from the principal vein of granite occupying the bed of the river. The strata cross the river there nearly at right angles, and dip at a large angle to the northwest. On the northeast, or Montgomery side of the river, at the distance of 40 or 50 rods, runs the Western Rail Road: and directly opposite the Falls, a ledge of granite and mica slate, 500 feet long, has been excavated, in some parts nearly 40 feet deep. The cut crosses the strata nearly at right angles; and Fig. 173 shows its northeast side. With one exception, where a portion of the strata is thrown out of place, it will be seen that the gran-

ite appears to form regu'ar beds in the slate. Thirty years ago, such a section would have been pronounced by many an indisputable evidence that granite was regularly stratified. Yet we have only to pass to the river, a few rods distant from this spot, and we shall see these same masses of granite, which here appear inters:r tified, proceeding from a master vein, as shown on Fig. 172, and entering the strata as lateral veins. Such an example shows the geologist how cautious he should be in drawing inferences before he fully understands the facts.

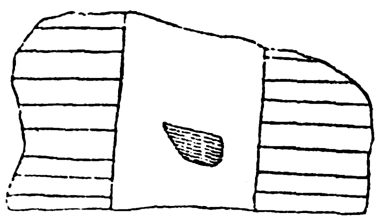
Fig. 173.



*Granite in Mica Slate: Montgomery.*

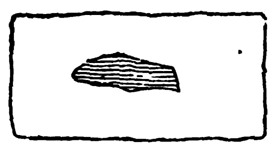
Figs. 174, 175, and 176, are representations of insulated masses of mica slate and gneiss in large veins of granite. The vein in Fig. 174, which is in the north part of Shutesbury, is ten feet wide, and the insulated mass of gneiss is almost three feet across in its longest direction. In Fig. 175, which is in Conway, the vein is fifteen inches wide, and the mass of mica slate (which is the rock traversed by the vein,) is thirty inches long. In Fig. 176, the imbedded mass of mica slate is eight feet wide and ten feet high; the layers standing perpendicular, and coinciding with those of the mica slate generally in that place. In all the cases described, it seems impossible to doubt but the schistose rock is perfectly insulated in the granite; and if so, does it not point to an igneous origin for the granite?

Fig. 174.



*Mass of Gneiss in Granite: Shutesbury.*

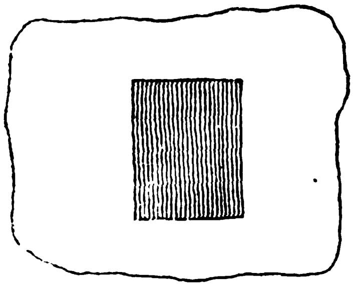
Fig. 175.



*Mica Slate in Granite: Conway.*

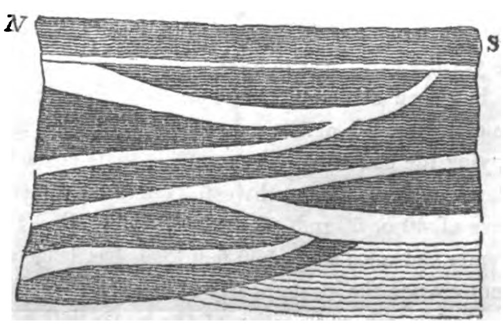
At Salmon Falls, on Westfield river, a mass of mica slate, having the same strike and dip as in the region generally, may be seen, not less than 4 rods in diameter, entirely enveloped in granite.

Fig. 176.



*Mica Slate in Granite: Chester.*

Fig. 177.

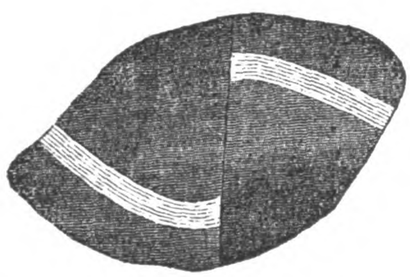



*Granite Veins in Granite: Whately.*

Veins of granite traversing granite are more frequent in Massachusetts than in any other rock. Generally the veins are composed of much coarser materials than the rock that contains them: and by this mark alone can they be distinguished, except that sometimes the color of the materials of the vein and that of the containing rock, are different. The case on Fig. 177 occurs in the west part of Whately, and exhibits a mass of granite of fine texture, about fifteen feet long and ten feet wide, with mica slate on one side. The dark part of the drawing represents this granite, and the white stripes crossing it are veins of coarse granite.

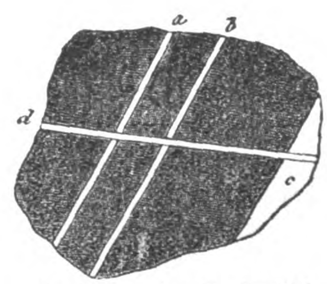
In Fig. 178, a coarse vein, made up almost entirely of feldspar, 20 inches wide, traverses a rather coarse granite. This vein has been cut off by a fissure crossing it nearly at right angles, and the two parts are separated seven feet. This lateral movement must have taken place after the consolidation of the rock. The case occurs in the southeast part of Newport, R. Island.

Fig. 178.



*Granite Veins in Granite: Newport, R. I.*

Fig. 179.




*Granite Veins in Granite: Gay Head.*

Fig. 179, represents an enormous bowlder of granite, from 20 to 30 feet in diameter, lying at the foot of the clay cliff at Gay Head, Martha's Vineyard. *a*, *b*, *c*, are granite veins of the same epoch; as is proved by their parallelism. These are all cut off by a vein *d*, of subsequent date, crossing them nearly at right angles Here then we have granite of three distinct epochs.

Fig. 180, shows us granite of four successive epochs of eruption. It is a sketch of a bowlder, 20 feet long and 10 feet thick, lying in Westhampton. The great mass of the rock belongs to the first epoch. The vein, *a*, *a*, *a*, was produced at the second epoch. This was intersected by *b*, at a third or subsequent epoch. This, as well as *a*, were intersected by the vein *c*, (and probably at the same time by *d*,) at a fourth epoch. The lateral removal of the middle portion of the vein *a*, seems to have resulted from the intrusion of the veins *b*, and *c*, whereby the wedged shaped portion of the rock between them was crowded out of its place.

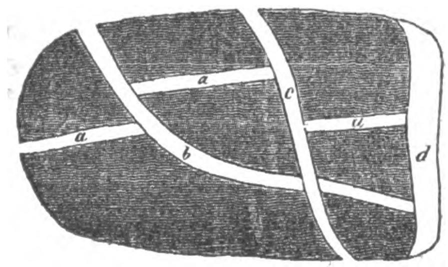
The next case is one of no peculiar interest, hardly worth preserving indeed. The sketch, Fig. 181, shows a vein of coarse granite, 10 inches wide, traversing a mass of finer granite, and cutting off and removing laterally another vein of coarse granite, 2 1-2 inches wide. It occurs in Southampton, not far from the spot where an adit has been made in the granite to reach a vein of galena.

Fig. 182, shows a granite vein a little more than a foot in width, crossing strata of gneiss obliquely. After this vein was injected, the strata of gneiss seem to have slidden down so as to cut off the vein in at least two places, and near those spots it is considerably reduced in size, as if in a plastic state when the disturbance took place in the gneiss.

The four next cases, viz. Figs. 183, 184, 185 and 186, were sketched in New Bedford and Fair Haven: all but Fig. 184, on Palmer's Island, in New Bedford Harbor. They all occur in gneiss. Fig. 183, is interesting chiefly on account of the peculiar form of the vein, which varies in width from two feet down to six inches. It exhibits the vein as it appears on the basset edges of the gneiss where the strata dip to the north about 35°.

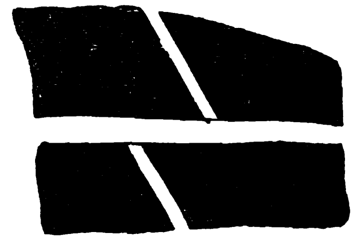
88

Fig. 180.



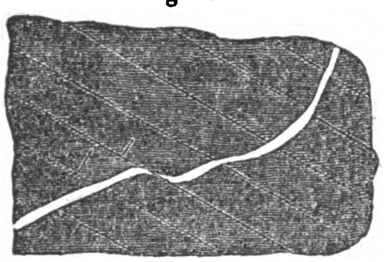

*Granite Veins in Granite: Westhampton.*

Fig. 181.



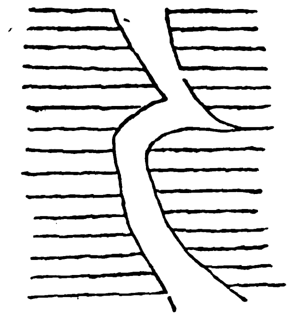
*Granite Veins in Granite: Westhampton.*

Fig. 182.



*Granite Vein in Gneiss: Shutesbury.*

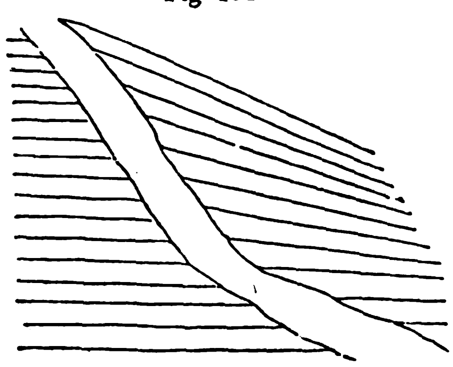
Fig. 183.



*Granite Vein in Gneiss: Palmer's Island, N. Bedford Harbor.*

The surface sketched in Fig. 184, is nearly horizontal; and the strata of gneiss dip as in the last case. On one side the direction of the strata is changed, apparently through the influence of the vein, as much as 10° or 15°. The vein is 15 inches wide.

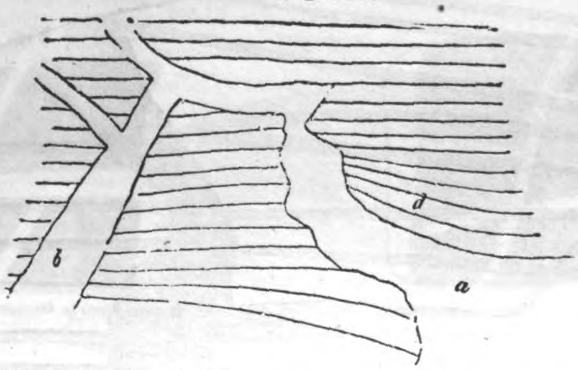
Fig. 184.



*Granite Vein in Gneiss: at the fort in Fairhaven.*

Fig. 185, exhibits also the basset edges of the gneiss strata where they dip 35° northerly. A mass of granite, *a*, which is several feet wide where it first appears above the soil, sends off a very crooked vein of six or eight inches wide, which connects with another vein, *b*; which last vein also sends off a narrow branch. At *d*, the edges of the strata are curved considerably, obviously in consequence of the granite in their vicinity.

Fig. 185.

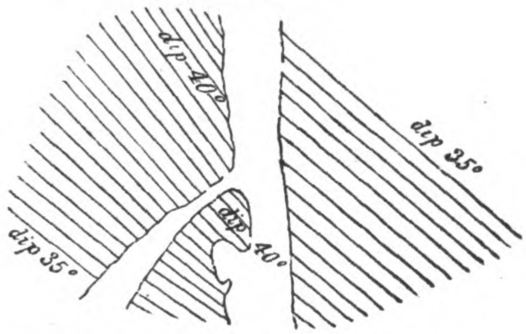



*Granite Veins in Gneiss: Palmer's Island, New Bedford Harbor.*

Fig. 186, is a nearly perpendicular section, running nearly north and south across the strata of gneiss, and showing an irregular branching vein. The principal vein is two feet wide, the branch about one foot. It will be seen that the general dip of the strata is 35°; and that it is increased to 40° on the lower side of the vein. The lower edge of the section corresponds to high water mark. The spot can be well examined only in a boat.

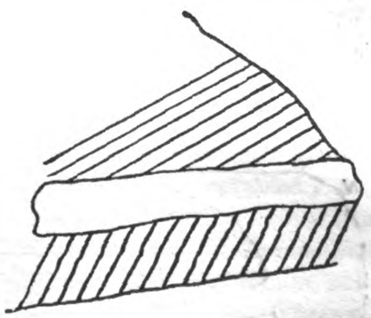
Fig. 187, was sketched from a bowlder of gneiss in the south part of Tolland. It is traversed by a vein of granite a foot wide. The only object is to show the change in the direction of the strata on different sides of the vein.

Fig. 186.




*Granite Vein in Gneiss: Palmer's Island, N. Bedford Harbor.*

Fig. 187.

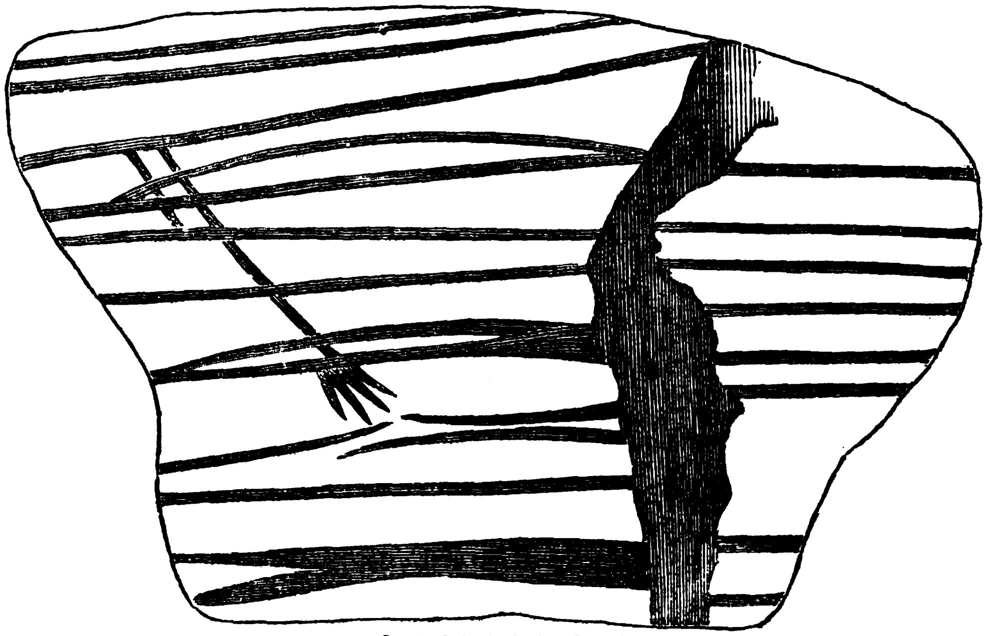


*Granite Vein in Gneiss: Tolland.*

Fig. 188, was sketched from a rock of granitic gneiss in the southeast part of Northfield, about 3 rods long. The shaded parts represent granite veins, and the unshaded parts, the gneiss. It will be seen that we have in this example veins produced at three successive epochs, if we follow the rule, which is generally safe, that a vein which cuts off another is to be regarded as the most recent.

In Fig. 189, a large protruding mass of granite rises from the soil at the north end of a naked ledge of mica slate, which is two rods wide, as represented on the sketch. From this mass of granite an irregular vein proceeds nearly in the direction of the layers of slate, embracing two or three nearly insulated strips of mica slate. It occurs in the west part of Whately.

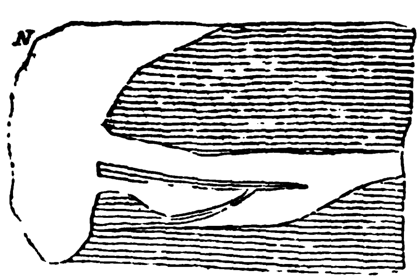
Fig. 188.



*Granite Veins in Gneiss: Northfield.*

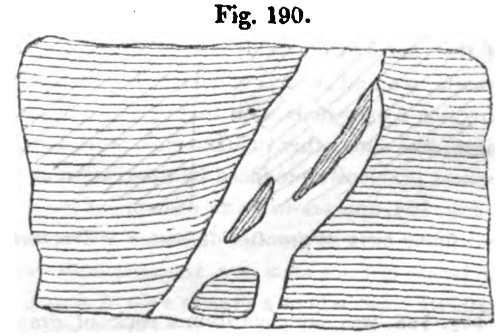
Fig. 190, is situated near the same spot. It represents the inclined surface of a ledge of mica slate, through which a granite vein of four feet wide passes. This embraces three masses of mica slate of considerable size, which are evidently separated entirely from the parent rock, except one of them nearest the upper side of the sketch. The layers of the mica slate, in the direction in which the granite was erupted, are obviously considerably curved, as is shown in the figure.

Fig. 189.




*Granite Veins in Mica Slate: Whately.*

Fig. 190.

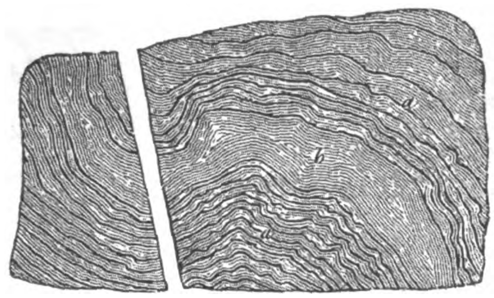


*Granite Vein in Mica Slate: Whately.*

Fig 191, represents a nearly perpendicular ledge of mica slate in Conway, very much contorted, about two miles southwest of the center of the town. *a, a*, are strata of common mica slate: *b*, is a stratum of amphibolic mica slate. The whole surface exhibited is fifteen feet long, and eight feet high. Through this ledge runs a vein of fine grained granite a foot wide. The object of giving the sketch is t show that this vein has produced no derangement of the mica slate: for the different varieties of that rock occupy the same relative position on the different

sides of the vein. Hence the vein was introduced subsequently to the consolidation of the slate; and probably it was injected into an open fissure.

Fig. 191.



*Granite Vein in Mica Slate: Conway.*

Fig. 192, was sketched only 100 rods northeast of the Congregational Meetinghouse in Conway. It represents two granite and several quartz veins, in coarse micaceous limestone. *a*, *a*, appears to have been the oldest granite vein, and is a foot wide on the right hand side of *b*, *b*, and twenty inches at the other extremity. This is intersected by another granite vein, *b*, *b*, and the two extremities are removed asunder forty-two inches. *c*, is a curved branch of this vein: *b*, *b*, is from twelve to eighteen inches wide. *s*, *s*, *s*, *s*, *s*, *s*, *s*, are quartz veins, from half an inch to two inches wide, and one of them, it will be seen, intersects both the granite veins; and, therefore, these quartz veins appear to have been of posterior origin to both the granite veins. *d*, and *g*, are masses of mica slate, with which (rock the micaceous limestone, that constitutes the dark part in the sketch,) is interlaminated in the vicinity. The direction of the layers of slate in the mass *g*, corresponds with that of this rock generally in the vicinity: but in what manner the mass *d*, should have been thrown at right angles to this direction, it seems difficult to imagine. It is obvious, however, that these granite veins have produced great disturbance in this spot.

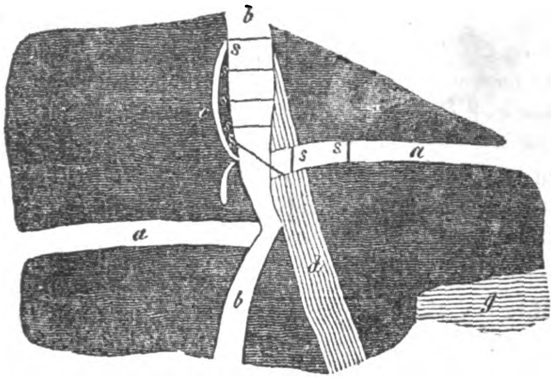
In the same town, and near the same spot, may be seen the original of Fig. 193. We have here a vein of granite, 40 inches wide, which sends off two branches; the first at an angle of 20° and the second at an angle of 50°. Both the branches are 18 inches wide, and the portion of the vein which continues in a direct course is 14 inches wide. Intersecting these veins of granite, we find several of quartz, whose width varies from one inch to three inches; and whose direction corresponds with that of the continuous layers of mica slate. The probability is that these, like most other quartz veins, were the result of the infiltration of siliceous matter into fissures previously produced by desiccation or mechanical force.

Fig. 194, appears to be an example of the mechanical effects upon the layers of mica slate of a protruding vein of granite. It occurs at Narrymore's quarry in the west part of Goshen; where the layers of mica slate are arranged with remarkable regularity. The dip there is about 40° northerly: but where a granite vein of four feet wide, (*b*,) protrudes in a nearly perpendicular direction, the strata of the slate on the lower side of the vein, for the width of eight inches, (*a*,) are bent so as to stand perpendicularly against the vein. On the upper side of the vein, and immediately in contact with it, the slate is hidden by soil: but it appears again a few feet distant at *c*. This example was brought to light by the quarrymen, and as it was sketched several years ago, ere this they may have destroyed all traces of it.

Fig. 195, represents a vein of granite, only one eighth of an inch thick, traversing mica slate in Conway, one mile southwest of the Congregational Meetinghouse. Strictly speaking, it is a bed; for it is interlaminated with the slate, and conforms to its tortuosities. It is not perhaps

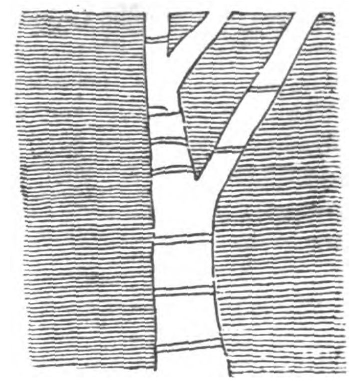
easy to conceive how such a vein could have been intruded between the layers of the slate, on account of its extreme thinness. Perhaps it ought rather to be regarded as one of the layers of the slate, produced in the same manner as the laminæ of gneiss.

Fig. 192.



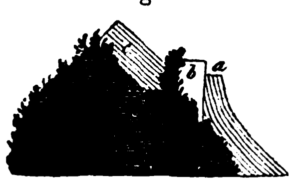

*Granite Veins in Micaceous Limestone: Conway.*

Fig. 193.



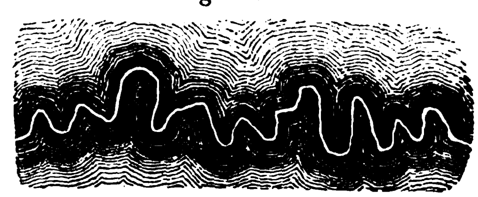
*Granite and Quartz Veins in Mica Slate: Conway*

Fig. 194.




*Granite Vein in Mica Slate; Goshen.*

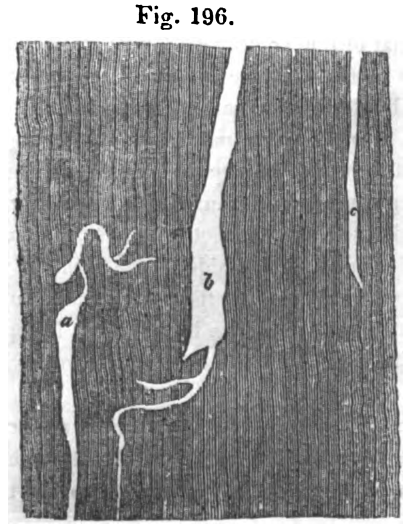
Fig. 195.



*Granite Vein in Mica Slate: Conway.*

Fig. 196, was sketched near the same spot. It represents the edge of a thick stratum of mica slate, whose dip is 50° east: and whose laminæ correspond in the dip to the strata seams. Among these laminæ and running in nearly the same direction, are three narrow and quite irregular granite veins. *a*, seems to have been injected from below, and has no apparent connection with *b*, which would seem to have flowed in from above. *c*, is a third very narrow vein only one fourth of an inch wide, which has no connection with the others.

Fig. 196.

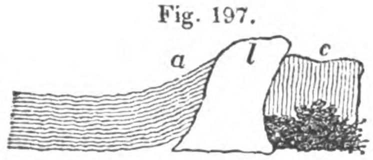



*Granite Veins in Mica Slate: Conway.*

Fig. 197, was sketched in Goshen, not more than a mile or two from Fig. 194, and it is analogous to Fig. 194. The spot may be seen two miles west of the village, on the old road to Cummington, on the margin of a pond. It is a ledge of mica slate a few feet high, whose strata dip from the observer, and whose basset edges only appear. On coming within 30 inches of the mass of granite *l*, the laminæ of slate are bent upwards 20°; and on the other side of the granite, *c*, they actually stand perpendicular or even lean a few degrees from the granite. The width of the protruding mass of granite, which is partly hid by the soil, is from three to four feet. It is common to see mica slate and other stratified rocks as much disturbed in the vicinity of granite as this case exhibits: but it is not common to meet with the disturbance on so small a scale.

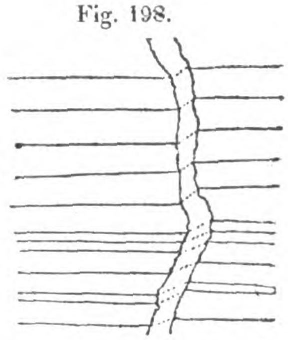
The mica slate in the northwest part of Norwich is frequently very regular in its stratification, dipping west 80°; and this is the case where Fig. 198, was sketched. A granite vein four inches wide crosses the strata nearly at right angles, and the edges of the mica slate show that the layers on opposite sides of the vein have been moved a few inches laterally. The distinctness of the stratification enables us to see this change more easily than is common.

Fig. 197.




*Granite Vein in Mica Slate: Goshen.*

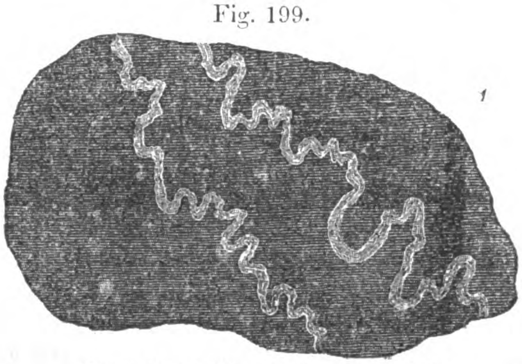
Fig. 198.



*Granite Vein in Mica Slate: Norwich.*

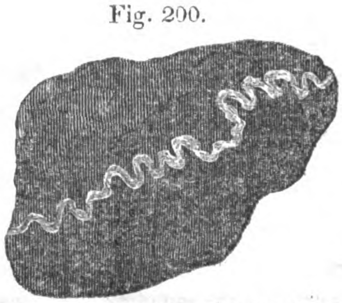
Fig. 199, represents granite veins in micaceous limestone in the west part of Colraine. They are bowlders of about two feet in diameter, and the veins only an inch or two wide. The extremely serpentine course of these veins is the most remarkable circumstance about them. For I could not discover any cause that makes them thus serpentine. The limestone appears perfectly homogeneous throughout, and is entirely destitute of any appearance of a laminar, slaty, or stratified structure: I mean so far as these specimens are concerned.

Fig. 199.



*Granite Veins in Micaceous Limestone: Colraine.*

Fig. 200.



*Granite Vein in Micacous Limestone: Colraine.*

The only remaining case of granite veins which I shall notice, is represented on Plate 55, at N. It shows a perpendicular wall of granite and mica slate, in Westhampton, on the stage road

from Northampton to Norwich. It is nearly 4 rods long. Several veins of granite are exhibited, which, for the most part, correspond in direction to the layers of mica slate.

In the preceding description of granite veins, I have noticed the bearings of nearly all the peculiar cases upon theory; and at the present day, it is hardly necessary to point out the general inferences that flow from these examples, as to the origin of granite: especially as I hope to present a summary of evidence on that subject, in the Fourth Part of my Report.

## *Mineral Contents.*

In every part of the world granite is the repository of very many of the most perfectly crystalized minerals: an evidence that its materials must have been once most thoroughly fluid. The number of species in the granite of Massachusetts is not quite as numerous as in one or two other rocks: yet it contains several of the most interesting minerals in the State.

Sulphate of baryta is extremely abundant in it; though the most prolific locality,—that in Hatfield,—occurs in sienitic granite, and has been described A considerable part of the matrix of the galena, blende, and copper pyrites, at the Southampton mine, consists of this mineral. The most southerly vein of lead ore in Leverett, also, abounds in it, as the gangue of the galena. And both the metallic veins in that place are in granite. The baryta occurs generally in foliated masses: sometimes in tabular crystals. The folia are sometimes curved; and sometimes, as in Leverett, the specimens are coarsely granular. The color is uniformly white.

Carbonate of Lime is rare in granite: but in the vein of metallic ores above spoken of at Southampton, we find it in distinct crystals; sometimes of a delicate straw color. I have observed there a dodecaedron composed of two six sided pyramids; a short six sided prism acuminated by three faces; also the same with all the solid angles of the prism truncated, producing a trapezoedron. This mineral more frequently is laminated.

The situation of the argentine in Westhampton, partly in the mica slate, and partly in the granite, renders it proper to speak of it as belonging to either rock: but under micaceous limestone, I have given a full description of its geological position; and its mineralogical characters correspond so well with those that are given in the books, that nothing more need be added. The locality cannot for a considerable time, be exhausted; unless it should be visited by some of those insatiable collectors, who carry away specimens by the ton. (Nos. 1490, 1491.)

This same mineral has been found at the Southampton lead mine.

At the most northerly vein of galena and pyritous copper in Leverett, I have found a few specimens of crystalized brown spar.

In Billerica and Stow, phosphate of lime has been found by Professor Webster in very coarse granite: also by Dr. C. T. Jackson, in the same rock in Lancaster, in connection with spodumene.

At the Southampton lead mine, green and purple fluate of lime has been found, but not in large quantities: though, should this mine ever be wrought extensively, there can be little doubt that abundance of it will be brought to light.

At the same place we meet with crystalized limpid quartz in great abundance. Sometimes the crystals are penetrated throughout by a yellow coloring matter, so as to form genuine yellow quartz. Radiated quartz forms the greater part of the gangue of the lead and copper ores, in the several veins of these metals that have been described as existing in Hampshire County, in the first part of this Report. In Chester, the quartz in this rock is sometimes rose red. In Goshen its crystals are sometimes of an extremely delicate smoke color; and in Williamsburgh, this variety occurs uncrystalized in large quantity, about two miles west of the Meeting House. In Bristol, Rhode Island, occur fine specimens of amethyst; which are said to proceed from the granite of Mount Hope. This locality a few years since promised something for the lapidary.

At the Southampton lead mine pseudomorphous quartz is sometimes met with. But the most interesting locality is in the galena vein, near the argentine locality, in Westhampton. The pseudomorphous crystals are very perfect, and have the form of double six sided pyramids and of cubes intersecting each other exactly like crystals of fluor spar. These crystals are hollow, and generally drusy without and within. It is now, however, very difficult to obtain specimens, especially of the variety that has assumed the form of fluor spar. (Nos. 1501, 1502.)

In Conway, I observed that some of the quartz in coarse granite was highly fetid. The same is found in Chester.

A mineral is sometimes seen at the Southampton lead mine, which appears to be hornstone. (No. 1502.)

Spodumene abounds in our granite. Goshen is its most abundant locality. About two miles north of the village, it occurs on the road to Ashfield; and also about three miles northeast of the center of the town, on the road to Plainfield, at a locality long celebrated for furnishing several interesting minerals. It is found likewise in Chesterfield, Norwich, and Chester. In all these places its characters are similar. It occurs in prismatic masses. These masses are sometimes four or five inches across, and of great length. Dr. Dwight of Cummington, showed me a specimen from Chesterfield, containing a prism 21 inches long, yet broken off at both ends. These larger masses are commonly of a white or gray color, and resemble feldspar. But the smaller specimens are frequently of a delicate green color, resembling very much the spodumene from the north part of Europe. A few specimens I have noticed of a light rose color. (Nos. 1504 to 1507.)

This mineral occurs also in Sterling, in a granite rock. This spodumene has more of a pearly aspect than that in the western part of the State; as the specimens in the collection will show. It is also of a more milky white color. (No. 1508.) In connection with the spodumene of Sterling, triplite is said to occur in small quantity.

The varieties of mica in our granite are numerous and interesting. The rose red, has been found only I believe in Chesterfield, and the northwest part of Goshen, where it sometimes occurs in oblique rhombic prisms; which is its primary form. In the same place, also, and likewise in the northwest part of Chesterfield, at the tourmaline locality, a delicate yellow mica of various shades is found under the same form; and still more frequently, a transparent or silver colored variety. But the most perfect crystals of mica which I have found in Massachusetts, occur at the beryl locality in South Royalston. (Nos. 2480, 2481, 2482.) The crystals are usually the primary form, viz. an oblique rhombic prism, and they vary in size, from half an inch to two or three inches in length. The only modification which I have noticed, is a truncation on the acute lateral edges as in the crystals of Lincolnite. (Fig. 146.) This truncation, which is not unfrequent, is usually slight, but sometimes deep. The color is smoke gray. In excavating the Western Rail Road at Warren, foliated masses of mica were blasted out of a large size, of which No. 2483, is an example, being one extremity of a truncated crystal. In some exceeding coarse granite in the northwest part of Norwich, I noticed plates of mica nearly two feet in diameter.

Prismatic mica is found in Goshen, Chesterfield, Norwich, and Leverett. But the specimens which I have found in Russell are the best. (Nos. 1512 to 1514.) The general color of the prisms is light smoke gray; but we sometimes see in them distinct strips, penetrating deep into the specimen, of a very dark bronze color; appearing black, indeed, except in very thin plates.

Plumose mica, (*Mica fibreux*, Beudant,) is quite common in Williamsburg, in several places west and northwest of the village. The name is derived from the resemblance between the arrangement of its lamellæ, and those of a feather; which indeed is often quite striking.

The granite of Massachusetts contains almost every variety of tourmaline that has been found on the globe. Common black schorl is most abundant. In Chesterfield and Goshen its crystals are sometimes large, but generally quite imperfect. In Norwich its crystals are terminat-

ed by pyramids. In Westford, also, I met with it in small very short acuminated crystals. (No. 1574.) In the coarse granite of Orange, it is common, and often in large crystals. It occurs also in great abundance in the south part of Warwick, although as the immediate gangue is quartz, I have placed it under quartz rock. (No. 2036.)

Of other tourmalines we have every variety, except perhaps the yellow and the white. Indicolite occurs at the greatest number of localities. In Chester, it is found in large crystals; also in connection with the green and red varieties in the northwest part of Goshen, associated with several other minerals: also in Chesterfield.

The most noted locality of green and red tourmalines is in the northwest part of Chesterfield, on land of Mr. Clark. They are contained in an enormous vein of granite in mica slate, which corresponds nearly in direction with the layers of the slate. This granite is crossed obliquely by a vein, varying in width from six to eighteen inches, of smoky quartz and albite: or rather, the quartz forms the central part of the vein, and the albite lies on each side of the quartz: the green, red and blue tourmalines, with schorl and sometimes beryl, passing through the albite and the quartz. This cross vein has been laid open from twelve to twenty feet by blasting; and it is really, in the eye of a mineralogist, a splendid object. I do not see that there is any prospect that it will soon be exhausted; although I doubt whether as fine specimens are now obtained from it as formerly.

The crystals of green tourmaline and rubellite at this locality occur in rounded prisms, deeply striated longitudinally. They have been found an inch in diameter, but generally they are much less, and the red ones are rarely more than one quarter of an inch: sometimes they exhibit triedral summits. It is very common for the rubellite to be enclosed in the green crystals, and sometimes a thin layer of talc intervenes between the inner and the outer crystal. Col. Gibbs found three of the red crystals in one instance aggregated together, and enclosed by one of green. The green crystals also sometimes embrace indicolite, and sometimes indicolite encloses the green tourmaline, as may be seen by the specimens, Nos. 1521, 1522, and 1524. The green tourmalines, as well as the rubellite, are sometimes entirely distinct from each other; especially when they are contained in the quartz. In some instances I have met with marks of rather singular disturbances which took place while the green tourmaline was crystalizing in the quartz. The quartz is fissured into somewhat parallel laminæ, and together with portions of the crystal has been subjected to a sort of *echellon* movement, while in some places it has been so compressed as almost to disappear. This last circumstance seems to indicate that the disturbance took place before the crystalization was completed. Fig. 201, is intended to represent this phenomenon.

Fig. 201.

*Crystal of Green Tourmaline in Quartz: Chesterfield.*

The colors of the tourmalines in Chesterfield are pretty uniform: but in Goshen they vary ex-

ceedingly. The rubellite is rarely met with there; but the indicolite is abundant; and this passes by numerous gradations into green tourmaline. Of some specimens, indeed, it is difficult to say whether they should be regarded as blue or green. There also we meet with a yellowish green tourmaline, (No. 1520,) which is associated with spodumene. Sometimes also I have seen this mineral nearly brown and even approaching to white. At Chesterfield the green variety is opaque: but some of its crystals at Goshen, penetrating mica, are translucent.

All the common varieties of feldspar are of course abundant in our granite. Its ordinary color is white. But in Leverett it is blue; and often the folia are six or eight inches across. In Goshen I have met with it slightly green. Albite is found as already noticed, at Chesterfield, where it is commonly foliated, but sometimes coarsely granular. (Nos. 1538, 1539.) At Goshen the same varieties occur: and that which is granular exceedingly resembles saccharine limestone. In Norwich it is found foliated and of a light blue color. At the other localities it is always white. Mr. Andrews of New Salem, finds it in white foliated masses in that town. It is found also in Chester. (Nos. 1535 to 1539.)

The localities of beryl in the granite of Massachusetts are numerous. With one or two exceptions, however, they yield only a few, and those, not rich specimens. It occurs at several places in Goshen, and sometimes in handsome crystals; but usually in opaque and dull specimens. A mineral occurs in the northeast part of the town, at a famous locality for many species of minerals, on what is called the Week's farm, which was formerly described as a rose beryl; being sometimes of a rose color, though usually hyaline. Professor Shepard, however, has more recently described this mineral as the phenacite. (*Am. Journal of Science, Vol.* 34, *p.* 329.) But Dr. Frederick Tamnau, of Berlin, in Prussia, to whom I sent specimens, says that "it seems not to be identical with the phenakite from the Ural, and from Tramont; and I wish particularly to have more of it for a chemical analysis." I have not found time to examine this mineral with the care requisite to decide with certainty as to its nature. But the chemical examination of it by Prof. Shepard, certainly renders it probable that it is the phenacite.

In Chesterfield and Norwich, beryls have been found of great size; but, as is usual in such cases, the size is at the expense of elegance. In Norwich, however, in the northwest part, some very good specimens occur. In Williamsburgh, also, quite elegant specimens have been found: and some, also, in Worthington. In all these cases, they exist in granite veins of the coarsest kind. In a similar granite vein I noticed some very large, but homely crystals, a mile south of the center of Warwick. In Rollstone Hill, in Fitchburg, some very good crystals have been found, and still better and more numerous ones on Pearl Hill, two or three miles north of the village in that place. The coarse granite of Stow, sometimes affords them. But by far the richest localities in the State, occur in Royalston and Barre.

The locality in Royalston is situated in the southeast part of that town, at a manufacturing village, sometimes called South Royalston, close by a school house, and on land of Mr. Clark. An enormous vein of coarse grained granite, 10 or 12 feet wide, traverses gneiss almost at right angles to its strike, and descends into it perpendicularly. This granite contains the beryls, which were first noticed by Alden Spooner, Esq. of Athol, who called my attention to the spot. Probably since that time one or two thousand specimens have been got out by myself and others; and I hope the locality is not yet exhausted; although as the excavation is now several feet deep, much more labor is required to obtain them.

I have never met with a beryl at this place more than about 2 or 2 1-2 inches in diameter. Such are usually more or less opaque, though sometimes nearly limpid. The larger crystals are sometimes more than a foot long; and they, as well as the smaller ones, are intersected by seams of quartz quite often. In such a case, the crystal is often bent where the quartz intervenes. The best crystals occur in gray quartz, but they are found also in the feldspar. The small crystals are frequently limpid; usually abounding in fissures; but sometimes so free from them,

as to admit of being cut and polished; and I have placed in the State Collection, a few specimens of the different varieties thus prepared by the lapidary. The varieties of color are three: the aquamarine, a grass green, and a yellowish green. The two latter colors are frequently quite deep, and the specimens approach in elegance to the precious emerald. The yellowish variety is the most beautiful; and when cut and polished, can hardly be distinguished from a chrysolite, which name was applied to it by the lapidary. In short, I am not aware that any locality of beryl in the United States, furnishes as fine and as numerous specimens as that at Royalston.

It is rare to obtain crystals with distinct terminations: but I have found several that were not ruined by getting out. Some of them have a single terminal plane. This is sometimes replaced by several planes, even as many as 8 or 10. The edges of the prism are sometimes replaced by one and sometimes by two planes; so that the prism has from 15 to 17 sides. Frequently these new planes are much less perfect than the sides of the original prism. But these complicated modifications cannot be explained without drawings, which I have not introduced, chiefly because of the crowded state of my report.

I have already described the fine crystals of mica that are found at this locality of beryl. Another mineral, much more rare, is Crichtonite, or Titanic Iron. It is in distinct crystals, with the sides and angles truncated. (No. 2510.)

The crystals of feldspar at this locality, are sometimes of remarkable size. No. 2511, is about 8 inches broad, and is so truncated as to become a flattened six sided prism, with dihedral summits, and a slight truncation upon one of the obtuse angles. Another crystal, which I obtained, was of similar form, and 9 inches wide, and a third was 20 inches wide, and about 8 inches thick; and yet it is a perfect crystal at one extremity! Another small crystal is so truncated on the edges, as to become an 8 sided prism, with the same terminations as above described. But figures are needed to illustrate these forms.

The beryl locality in Barre, is situated in the extreme west part of the town, near the road to Dana; and its general characters are the same as those of the Royalston locality: that is, it is a huge vein of coarse granite in gneiss. Crystals of feldspar occur here, also, as large as those in Royalston. But the beryls are far less numerous and rich. Some tolerable specimens, however, have been obtained; and the modifications of the primary form are similar to those already described. In connection with these minerals, we sometimes find garnets, nearly an inch in diameter. But the most interesting mineral at this locality is rutile. It occurs in distinct crystals, usually insulated; and some of them are really magnificent; being from an inch to an inch and a half in diameter. Sometimes we find the right square prism truncated on the edges, with tetrahedral summits. But more usually the crystals are geniculated. This mineral is not abundant at this locality. But a good deal of blasting will usually be rewarded by several specimens.

Specimens of all the preceding minerals from Royalston and Barre, will be found in the State Collection.

In the granite of Chesterfield, Professor Shepard has described a new mineral, chiefly an oxide of cerium, which he has named *microlite*, from the minuteness of the crystals: none having been found which weigh half a grain. In the same place he has found the uranite in small quantity; which is a cupreo-phosphate of uranium. Variegated copper ore is said to have been found in the Chesterfield granite. The Columbite, which is chiefly columbic acid and iron, has been found in right rectangular prisms, with several modifications, at the tourmaline locality in Chesterfield: and also at two places in Goshen, imbedded in spodumene. Thus we find that in this region there exist several of the rarest metals on the globe.

Garnet is less abundant in our granite than in several of the older stratified rocks. Generally

where it does occur, it is in quite small crystals; but it is commonly the precious garnet. In Bedford it is said to be found in large and sometimes perfect trapezoidal crystals.

I believe that all the veins marked on the Geological Map, as lead veins, in Hampshire County and the south part of Franklin, are either entirely contained in granite, or pass from that rock into mica slate. Hence the minerals which they contain may properly be described in this place.

The gangue of the most southerly vein in Leverett is sulphate of baryta and quartz. It is only a foot or two in width, and is entirely in granite. It contains galena only. The most northerly vein in that town is several feet wide, and is mostly in mica slate. It contains galena and pyritous copper in nearly equal proportion.

The vein in Southampton to which I have often referred, and which has been explored farther than any other in the State, traverses granite and mica slate; and the gangue is mostly quartz with sulphate of baryta occasionally. Its extent and situation have, however, been already given in the first part of my Report with sufficient minuteness. Galena is the principal ore. Blende, however, is frequent, as well as pyritous copper. Here also have been found the carbonate, molybdate, sulphate, phosphate, and murio-carbonate of lead; the blue and green carbonate of copper and vitreous black oxide of iron. Here also we find sulphuret of iron in small octahedra, truncated on all their angles. The carbonate of lead is found in tabular prisms with bevelments: also in six sided prisms with four sided acuminations: also in triangular dodecaedra with their apices deeply truncated. The murio-carbonate of lead is in light green groups of cubic crystals terminated by tetraedral pyramids. The sulphate of lead occurs in small plates on the galena. The phosphate of lead exists in spherical light green masses.

The vein in the south part of Southampton is said to have a gangue of quartz containing galena, and to be not more than a foot wide. I have not visited it.

About a mile northeasterly from the adit in Southampton, and I believe within the limits of Northampton, a vein of quartz mostly radiated several feet wide, traverses mica slate chiefly, and contains blende and galena; the former in much the greatest quantity. The blende here, as well as at all the veins in the vicinity, is foliated, rarely in distinct crystals, and of a honey yellow color.

The metallic vein in Westhampton, near the locality of argentine, is very large, at least 10 feet wide: though I could not ascertain its true width. It is composed entirely of radiated and crystalized quartz, surrounding small masses of some other rock, probably mica slate, the whole mass having a brecciated appearance. Galena, the only ore that has been found here, is very sparingly disseminated. I could not ascertain whether this vein is in granite or mica slate; both of which rocks occur in the vicinity.

The veins in Williamsburgh, according to Mr. Nash, occur in granite and mica slate, and the gangue is quartz. Only one of them, however, has been discovered in the rock, their existence being inferred from the loose blocks strewed over the surface. In at least one of these veins, the oxide of manganese occurs, along with galena. Pyritous copper exists there also, in small quantity: and I found foliated blende. This latter ore appears to have a strong tendency to decomposition, and often the cavity that contained it, is filled with a dull red powder, whose true nature I have not ascertained.

The three veins in Whately have all a gangue of quartz, generally radiated. The most easterly one, according to Mr. Nash, contains oxide of manganese as well as galena. The most northerly one, is six feet wide and lies chiefly in granite. It contains blende as well as galena. The two other veins described by Mr. Nash I have tried in vain to find.

In the first part of my Report, I have described a vein of quartz, containing blende in abundance, as well as porcelain clay, in Norwich; owned by Quartus Angell; and also a vein of quartz near Great Falls in Russell, from 2 to 4 feet wide, and 300 feet above the river, contain-

ing galena and blende. Both these veins, especially that in Norwich, contain very beautiful drusy and crystalized quartz; as may be seen by examining Nos. 2487 to 2496.

According to the Messrs. Danas, muriate of copper has been found in rolled masses of granite in Woburn.

It is said, also, that specular oxide of iron occurs in Mendon, and in Cumberland, R. Island, in granite.

In the 16th volume of the American Journal of Science, I have given a very particular account of the single crystal of the oxide of tin, which I found several years ago, at the well known locality of several interesting minerals in the northwest part of Goshen. Its form, if I did not mistake it, was an octahedron with a square base. It occurs also in the granite of Chesterfield; so that we are now certain of three localities of this valuable metal in Massachusetts, and within a year or two, it has been found in Connecticut and New Hampshire.

Sulphuret of molybdenum has been found in granite in New Bedford and Fitchburg.

Reserving all theoretical considerations as to the origin of granite for the Fourth Part of my Report, I shall proceed to notice a few miscellaneous subjects that could not well be introduced previously.

## Miscellaneous Subjects.

### 1. *Metallic Veins and Beds.*

On Plate 53, will be seen, as indicated by double arrow heads, the strike of most of the metallic veins and beds in Massachusetts, where they have been sufficiently opened to ascertain these particulars. The facts, on which that delineation was founded, are the following.

| | *Strike.* | *Dip.* |
|---|---|---|
| 1. Bed of Iron in Hawley. | North and South. | Vertical. |
| 2. do. Somerset, Vt. | do. | 20° to 30° E. |
| 3. Bed of Manganese, Plainfield, (S. W. part.) | do. | nearly 90° E. |
| 4. Vein of Lead, (most Southerly) Leverett. | do. | nearly Vertical. |
| 5. do. Whately, (North part.) | do. | do. |
| 6. Vein of Copper Ore on Island, Turner's Falls. | do. | Westerly. |
| 7. Vein of Copper Ore in Greenfield, near Turner's Falls. | do. | Vertical |
| 8. Vein of Manganese, Conway. | N. E. and S. W. | do. |
| 9. Vein of Lead, and Copper, Leverett, (most Northerly Vein.) | do. | |
| 10. do. do. Southampton. | do. nearly. | do. |
| 11. do. do. Westhampton. | do. | do. |
| 12. do. do. Zinc chiefly, Northampton. | do. | do. |
| 13 and 14. Two Veins chiefly in Whately, (on Mr. Nash's authority.) | do. | |
| 15. Bed of Copper Ore, Granby, Ct. | do. | 20° S. E. |
| 16. Bed of Mag. Oxide of Iron, Bernardston. | N. E. and S. W. | do. |
| 17. Bed of Plumbago, Sturbridge. | N. 30° E. | 60° to 70° N. W. |
| 18. do. Iron and Zinc, Sterling. | N. several degrees E. | do. |
| 19. Vein of Lead, Hatfield. | nearly N. W. and S. E. | Vertical? |
| 20. do. In Russell. | N. and S. | 90°. |
| 21. do. In Uxbridge. | N. E. and S. W. | 25° S. E. |
| 22. Bed of Limonite, W. Stockbridge. | N. and S. | 45° E. |
| 23. do. Of Magnetic Oxide of Iron, Chester. | do. | 90°. |
| 24. do. do. Warwick. | do. | 90° nearly. |

## 2. *Geological Map.—(Plate* 52.)

I have little to add to the explanations that have already been given respecting the Geological Map, on Page 305. My resurvey of the State has enabled me to make numerous minor alterations and corrections of the former editions: but the scale of this Map is too small to allow of numerous lesser alterations and additions, which I have it in my power to make. I had cherished the confident expectation, that before my re-examinations were completed, the large Map of the State, now in progress under the superintendance of Mr. Borden, would have been published. But being disappointed in obtaining that as the basis of the Geological Map, I have resorted to the best published Maps of the State for this purpose. And on this account, I thought it not judicious to construct the Map on a very large scale. For at the best, it can be considered only as an *Index to a Geological Map* of the State. Whenever the large Map shall be completed, if life be spared, and the Government wish, I shall be ready to color it geologically.

## 3. *Map of the Strike, Dip, &c. of the Strata.—(Plate* 53,) *and Sections of the same.—(Plates* 54, *and* 55.)

Although I have given numerous local details respecting the strike and dip of the strata, yet so numerous are the anomalies in these respects, that I thought it necessary to represent the predominant strike and dip upon Plate 53. Local deviations, unless on a large scale, are not there represented. On the same Map I have exhibited several other subjects of importance; such as the Axes of Elevation, and Depression, the Systems of Strata, Diluvial Furrows, &c. Some of these have been already explained, and the others will now receive attention.

The instruments which I have employed for ascertaining the strike and dip of the strata, are a good pocket compass and a clinometer. I confess, however, that in consequence of the very common changes of the dip and strike within short distances, I have been much in the habit of depending upon the *coup d'oeil* to obtain their average: having first ascertained where the true meridian lay, and having found by long trial that I could be more accurate in this way, and especially in respect to the dip, than by the use of instruments. But after all, every geologist must be aware that all observations of this kind, made in the best manner, can be only approximations to the truth. In most instances, however, they come sufficiently near the truth to form a good basis for reasoning: since it is large differences only, in the dip and strike, on which the conclusions rest.

In strictness, when the direction is given in this Report in degrees, about 8 degrees should be allowed for the westerly variation of the magnetic needle.

Dotted lines are drawn on the Geological Map to show where the Sections, given on Plates 54 and 55, cross the country. Section A, crosses from east to west near the northern part of the State. Section B, is intended to cross near the middle of the State: though it deviates somewhat from a direct course, in order to strike Wachusett. Section E, passes through the southern part of the State; though when it reaches the northern corner of Rhode Island, it tends more to the south, in order to terminate upon the famous 'Plymouth Rock,' which is a large bowlder of a rather peculiar kind of granite. (No. 1433.) Section F, passes from the northeast corner of the State to Boston; thence it changes its course slightly to reach Newport, R. Island. Section C, exhibiting Gay Head of the natural colors, has already been explained. Section D, crosses Mount Toby; Section G, Mount Tom; and Section H, the central parts of West Stockbridge: and their object is to give an idea of the structure of interesting spots which are out of the course of the general Sections. The other smaller sketches on Plate 55, have already been described.

The horizontal scale used in all these sections, as far as G inclusive, corresponds with that on

the Geological Map: so that the larger Sections are of exactly the same length as the Map, measured on the dotted lines above described. Hence any particular spot on the Section may be found upon the Map, by laying the one upon the other. The scale for laying off the heights is 2000 feet to the inch.

The height of the most important points was obtained from the accurate results of the Trigonometrical Survey by Mr. Borden. (*See Monthly Chronicle, for July* 1840, *p.* 185.)

The double scale necessarily employed in extensive Sections of this kind, gives so distorted a representation of the surface, and consequently of the relative situation of the different rocks, as exceedingly to diminish the value of such representations. Geologists accordingly at the present day, are very jealous of them, and value them less as they are more distorted. 'Such Sections,' says De la Beche, 'are little better than caricatures of nature, and are frequently much more mischievous than useful, even leading those who make them to false conclusions, from the distortion and false proportions of the various parts.' (*Geological Manual, 2d Ed. p.* 545.) If to this it be added, that there is a strong temptation to make up for a deficiency of observation by giving the relative position of rocks according to a favorite theory, we shall be persuaded that many of the Sections hitherto published, have conveyed to the mind nearly as much error as truth. A Section which exhibits only the truth, so far as the observer has ascertained it from actual examination, forms too naked and uninviting a sketch to satisfy the taste or ambition of many. Hence the imagination and the painter are taxed to make up the deficiency.

In the Sections appended to this Report, however, I have endeavored to present the dip and superposition of the rocks, only so far as I have determined these points from actual observation. Where, for instance, I have not seen the actual junction of different rocks, I have left a blank space between them. Notwithstanding these precautions, I am afraid that these Sections will convey some erroneous impressions.

The principal object of these Sections is to exhibit the actual dip of the strata; and this I have endeavored to give without reference to the distortions of the surface.

## 4. *Axes of Elevation and Depression.*

Although we have several distinct systems of strata in Massachusetts, yet the anticlinal and synclinal axes are few and not well marked. Strictly speaking, I have traced out but one of the former, unless we regard the summit of Hoosac Mountain as another. But I have in another place attempted to show that this may be a folded axis with inverted strata; and it does not seem proper to call this an anticlinal axis. Hence I have marked the axes in the State on the Map, as Axes of Elevation and Depression.

The Axis of Elevation above mentioned, runs along the gneiss region a little west of the valley of Worcester. The westerly dip, as we pass westward from that line, soon becomes considerable: but the easterly dip, till we reach Worcester valley, is very small. Yet I cannot but conclude that a real anticlinal axis runs near where I have marked one on the Map. Towards its southern part, it is interfered with by a N. E. and S. W. system of elevation, extending northeasterly to the mouth of Merrimack river. That system has a very uniform northwesterly dip; but the same dip continues until we reach the unstratified rocks along the eastern part of the State; and those rocks probably form the axis of a system of strata, whose southeastern side is covered by the ocean, or removed by denudation. The same thing seems to be true of the strata of gneiss and graywacke running east and west in the eastern part of the State. Whether an anticlinal axis will be found in Rhode Island, or Connecticut, answering to the strata in Massachusetts, on the borders of those States, running N. W. and S. E. and dipping N. E., I am unable to say. I suspect, however, that that strike and dip prevail over a considerable part of Rhode Island.

I have marked on the Map two synclinal axes. The most westerly runs through the valley of the Connecticut. In this case, however, I refer chiefly to the primary strata on opposite sides of the valley; for the dip of the sandstone is uniformly to the east across the whole valley I suppose the sandstone to have been deposited, not till after the formation of a valley of depression: then only the primary strata on the west of the valley subsequently experienced an upheaving, which tilted up the sandstone on that side only. I do not find evidence that this synclinal axis extends entirely through this valley: for to the north of Turner's Falls, the primary strata, which here occupy most of the valley, all dip easterly.

The other synclinal axis passes through the valley of Worcester. Here is a good deal of uncertainty as to the exact line along which it ought to be traced. I have drawn it in a curved direction, as near as possible to the place where the rocks are tilted up in opposite directions. But the dip is very irregular along that line; and on the west side it is very small. Yet at no great distance on both sides of the synclinal axis which I have drawn, the predominant dip is in opposite directions. On the east side it is much the greatest; and the principal upheaving force seems to have operated there.

### 5. *Systems of Strata.*

When the strike and dip of the rocks over any considerable districts are traced out and placed upon a Map, we usually find more than one system of strata, each occupying a particular region. The strike and d p of the same system have a general agreement; unless an anticlinal axis pass through it, when the dip will be different on opposite sides of this line. We find, for example, one set of strata running north and south, and dipping east: another running east and west, and dipping north; a third, whose strike is northeast and southwest, and its dip northwest. Where these systems intersect, a good deal of confusion often results. But sometimes the latest system crosses the older ones, and manifests itself in distinct districts, separated by patches of the older systems along the same general course.

We owe it to the masterly generalization of some modern geologists, especially Elie de Beaumont, that we are able to assign as a cause of these phenomena, that the different systems were elevated at different epochs, by forces acting along extended lines. In other words, geologists are now able to solve the sublime problem, which determines the relative ages of different systems of strata and chains of mountains.

I think we can trace in Massachusetts six distinct systems of strata, which were tilted up at various epochs. The almost entire absence of most of the newer strata in this State, however, throws a great difficulty in the way of settling the exact order in which these systems were thrown up. I shall now present a brief view of these systems, in the order of their age; beginning with the oldest: although in respect to some of them, the evidence as to their age is extremely slight.

### 1. *The Oldest Meridional System.*

I embrace in this system all the primary rocks lying between the valleys of the Connecticut and Worcester, except a small patch in the southeast part of the range. I call it *meridional*, because the strike of the strata is usually not far from north and south; though the general course is in fact several degrees east of north. I consider this system the oldest in the State for the following reasons. In the first place, it appears to have been elevated before the deposition of the new red sandstone in the valley of the Connecticut: for the dip of that rock throughout is easterly. Consequently this sandstone must have been lifted up by a force acting beneath its western edge: the same force that elevated the primary region of Hoosac Mountain: and, therefore, this latter mountain must have risen at least in part at a later epoch than the primary range east of Connecticut river. In the second place, we find the mica slate of Worcester and Merrimack valleys dipping at a much greater angle on their southeastern than their northwestern side; which affords a presumption, though no certain proof, that the ridge on the east side has been more recently elevated than on the other side. The rocks on the eastern side run N. E. and S. W. and form a very distinct system. If I mistake not, this system extends west of the valley of Worcester, and has interfered with the Oldest Meridional System, throwing the strata into a N. E. and S. W. direction; though not a little irregularity in their strike and dip exists. This fact shows that the northeast and southwest system was more recently elevated than the meridional system. I conclude, therefore, that the latter is the oldest in Massachusetts; because it is older than the Hoosac Mountain range and the northeast and southwest system, above referred to. For I think it will be rendered probable in the sequel, that all the other systems are more recent.

I have reason to suppose that this system extends northerly, so as to embrace the highest land in New England, viz. the White Mountains of New Hampshire. In this I may be mistaken; as the careful examinations necessary to establish this point, have not yet been made.

### 2. *Northeast and Southwest System.*

The gneiss range occupying the southeast part of Worcester County, the central parts of Middlesex, and a part of Essex, exhibits more uniformity of strike and dip than any other range in the State. The mica slate connected with it on its northwestern side, has more irregularity in its position; and as we enter the valley of the Merrimack, the strike becomes nearer to east and west. Still I cannot doubt this rock belongs to the same system as the gneiss. And yet I strongly suspect that the mica slate may be found to be less tilted up than the gneiss; which would show that the latter was partially elevated before the deposition of the former. A portion of the graywacke strata, along their northwestern border belongs also to this system. But in scarcely any place do the gneiss and graywacke come in contact; and, therefore, we have no reason to infer that the latter passes beneath the former; as I suppose to be the case in Berkshire County and New York.

I think that any one who will examine the strike and dip of the various deposits of graywacke in Massachusetts, whether he examines them in the field or in the details which I have given on this subject on page 539, will conclude the most distinct system of strata to be that under consideration. And though it is difficult to avoid the conclusions that an east and west as well as a northwest and southeast system appear in the formation, yet throughout the whole of it, there seems to be a tendency, if I may so express it, towards a northeast and southwest system. These considerations have led me to the conclusion that the latter is the oldest system, and that the others are rather subordinate systems; which appeared subsequently and broke up the regularity of the first; wheeling the strata round more towards an east and west strike. These are

certainly very equivocal proofs that the northeast and southwest system is the oldest: but I can discover no better ones by which to settle the age of this system.

The northeast and southwest system corresponds in direction almost exactly with that of the principal ridges of the Appalachian and Alleghany Mountains, in the Middle and Southern States; and also with those ranges that stretch from New England northeasterly, almost to Labrador. I incline decidedly to the opinion, that these ridges, although nearly parallel, embrace at least two distinct systems of elevation. But I cannot doubt that one of these systems is an extension of that which I call the Northeast and Southwest System in Massachusetts; and I suspect it to be that system of primary rocks, which, in the Middle and Southern States, succeeds immediately on the northwest to the secondary and tertiary groups. Gneiss is there a predominant rock; and often at least dips to the northwest. As we go northeast from Massachusetts, we find this system extensively developed in Maine after getting beyond Casco river. According to Dr. C. T. Jackson, it continues even to the northeast extremity of the State. (*First Report on the Geology of Maine*, *p*. 63,) and I doubt not but it will be found to extend even to Labrador. It may be, also, that the nearly parallel strata of gneiss, mica slate, &c. extending along the north shore of the St. Lawrence, even as far West as Lake Huron, belong to the same system. This is the Pyreneo-Appenine System of Beaumont; and he supposes that it not only embraces the Appalachian Mountains of the United States, but also the Pyrenees, a part of the Appenines, the mountains of the Morea, and the Hartz mountains in Europe; Mount Atlas in Africa; and Mount Carmel, Sinai, the Caucasian and Ghaut Mountains in Asia. But it will surely require far more extended and accurate observations than have yet been made, in these widely separated parts of the world, before such a generalization as this can be admitted.

## 3. *East and West System.*

The oldest stratified rock in this System, is the gneiss around New Bedford; whose predominant strike is east and west, and the dip north. The only other stratified rock embraced in it, is the graywacke: a large part of which corresponds in strike and dip to the gneiss just mentioned. At least, I do not find the dip of the graywacke so decidedly less than that of the gneiss, as to forbid the idea that they are of cotemporaneous elevation. A large part of the sienite, porphyry, and greenstone, extending across the eastern part of the State, appears to be connected with this system. Indeed, were it not for the east and west direction of some of the ranges of these unstratified rocks, I should doubt whether there were sufficient evidence that the stratified rocks above described, ought to be regarded as a distinct system, or the result of local deflections in the northeast and southwest systems. But when we find the porphyry range on the north of Boston, and especially the Blue Hills on the south of Boston, the highest ridge in the eastern part of the State, running east and west, it seems difficult not to admit the east and west system to be independent of all others: especially when we find, south of the Blue Hills, as in Sharon, Foxborough, and other places, some unstratified ridges, such as the Moose Hill range, which is 400 feet high, running N. E. and S. W.; and thus corresponding to the graywacke in the intervening valleys.

The very imperfect evidence from which I have inferred the system under consideration to have been elevated subsequently to the northeast and southwest system, has been already presented. Whether this system exists in other parts of our country, I am unable to determine. So far as we can judge from the direction of mountain ranges, such a system must be more rare than any other.

## 4. *Hoosac Mountain System.*

This system embraces all the rocks between Connecticut and Hudson rivers, except the trap and new red sandstone near the former. The strike is usually several degrees east of north and

west of south ; being parallel to the oldest meridional system. But as stated in another place, the Hoosac Mountain system appears to have experienced a vertical movement since the deposition of the new red sandstone : whereas we have little or no evidence of any such movement in the oldest meridional system. I therefore infer the former to be the newest. But as to the relative age of this system, and that of the east and west system, already described, we have no means of deciding ; because they no where come in contact, and are separated by a wide area. We might, perhaps, raise a presumption that the Hoosac Mountain system is the newest, from the fact that it has experienced a vertical movement since the deposition of the new red sandstone ; whereas the east and west system has elevated only the graywacke. But unfortunately the new red sandstone does not exist in the region where the latter system prevails. If I am not mistaken, however, in supposing a part of what is marked upon the Geological Map as graywacke, to be the coal formation, we shall have the rock next older than the new red sandstone tilted up, as a part, both of the east and west and the northeast and southwest systems ; and hence it is very probable that had the new red sandstone existed there, we might find that elevated also.

The system under consideration embraces that extensive series of vertical and inverted strata, extending in width from the Connecticut to Hudson rivers, and forming several folded axes. I have already given so full an account of this series of strata, that nothing further need be added here. That it extends from Canada to Tennessee I have little doubt. Along the western part of New England, and the eastern part of New York, its general strike does not vary many degrees from the meridian. But south of Connecticut, it curves towards the west, and continues almost a southwesterly course nearly to the Mississippi ; embracing the western part of the Alleghany Mountains. I suspect it to be the most extensive system on the Continent. It would not surprise me if it should be found to extend southerly far into South America, and northeasterly into Labrador.

### 5. *New Red Sandstone System.*

This System embraces only the sandstone and trap in the valley of Connecticut river. Perhaps I ought to have included it in the Hoosac Mountain System. For I have little doubt but the elevation of the sandstone was due to the latest vertical movements of the Hoosac Mountain System. But as the latter had obviously attained its principal elevation before the deposition of the sandstone, and as a part of the present inclination of the latter is due to the agency of the trap, at least in several localities, I have separated this system from the Hoosac Mountain System. For I have regarded a general correspondence of dip as essential to bring rocks into the same system ; although this may be a more limited sense of the term than has been usually adopted. In the present case, also, I think that there is not a perfect parallelism between the sandstone and the mica slate of the Hoosac range : for the sandstone appears to me to run more to the east of north and the west of south, than the mica slate on which the sandstone rests unconformably.

A similar new red sandstone, accompanied with trap, is found in Nova Scotia, New Brunswick, and the northeast part of Maine : also in New Jersey, and extending from thence through Pennsylvania, Maryland, and Virginia, into North Carolina. The strike and dip of the strata, however, do not correspond generally with those of the Massachusetts sandstone ; and therefore, perhaps these deposits cannot properly be referred to the same system of strata, though most likely they are of the same age.

### 6. *Northwest and Southeast System.*

It will be seen by Plate 53, that this system occupies less surface in Massachusetts than any

other. I have marked it only in the southern part of the State, upon the borders of Rhode Island. But I have reason to believe, from what I have seen of the primary rocks in the latter state, that this system is more widely developed there than in Massachusetts. The strata embraced by it are chiefly of gneiss; though we sometimes find the graywacke with a correspondent strike and dip: but whether belonging to this system I cannot say. The strike of the system is pretty uniformly N. W. and S. E. and the dip N. E, but rather moderate.

In the town of Warwick the mica slate and hornblende slate often approach in their strike and dip to this system, as they do in Winchester, the town in New Hampshire north of Warwick. Possibly the strata there may belong to the northwest and southeast system: for the strike of the strata in the southeast part of the State, prolonged northwesterly, would cross this region. Yet I am too much in doubt on the subject to reckon these rocks as a part of the system. I have less doubts in regard to a region extending nearly from Portsmouth in New Hampshire, to Saco river in Maine. If I do not greatly mistake, the strike and dip there correspond with those of the system under consideration. By referring to my description of the eocene tertiary strata at Gay Head, on Martha's Vineyard, it will be seen that their strike and dip correspond almost exactly to those of this system; and if we prolong its strike southeasterly from Sutton, Mendon, and Uxbridge, the line will come near Gay Head. I cannot but suspect, therefore, that the eocene tertiary of that spot was elevated at the same time as the older members of this system: and it is on this fact alone that I regard it as the most recent system in the State.

Northwest and southeast is an unusual direction for a mountain ridge in the United States, or any other parts of North America. But Dr Richardson has described the northern parts of the Rocky Mountains, in the northwest part of the country, near the Northern Ocean, as composed of four chains of primary rocks, having nearly a northwest and southeast direction: and that region lies nearly northwest from Massachusetts, reckoning upon a great circle. I merely mention the fact, however, without regarding it as any decisive proof that strata so remote from each other have a connection. The thing, however, is not impossible.

It is an interesting fact, that where the northwest and southeast system intersects the northeast and southwest system, on the borders of Rhode Island, is one of the most metalliferous spots in New England; and that the evidence of metamorphic agency is perhaps more striking here, than any where else in Massachusetts, Rhode Island, or Connecticut. These effects are just what we might expect by the principles of geology; since the strata must be exceedingly fractured in such a place, and thus make way for the egress of internal heat and sublimated matters.

Some other facts relating to the tertiary and newer secondary strata on this continent, deserve to be mentioned in this connection. The labours of Professor Vanuxem, Dr. Morton, Mr. Conrad, and others, have shown that as we go southerly from New York, the tertiary and chalk formations first appear on the continent in New Jersey, and from thence extend through all the middle and Southern States, as far as Alabama, and even as far northwest as Missouri. Along the eastern part of the United States, their extent is more than 2000 miles. And throughout their whole extent, they continue to rise higher and higher upon the primary rocks, from New Jersey to Alabama. At the north part of New Jersey, they pass under the ocean; but the tertia-

ry strata reappear in Long Island, and in great distinctness at Gay Head on Martha's Vineyard. Still farther to the northeast, some of the higher members of the tertiary, or perhaps only diluvium, show themselves on Nantucket. But beyond that island, no tertiary strata of consequence have been found, until we reach the coast of Greenland. *(Morton's Synopsis of the Organic Remains of the Cretaceous Group of the United States:* 1834*: Also Beaumont's Recherches sur quelques-unes des Revolutions de la Surface du Globe:* 1830.) Passing south from the United States, we find tertiary strata in the West Indies. In South America, the chalk formation shows itself, and constitutes, indeed, all the secondary rocks of the Andes, from 10° North Latitude to 15° South Latitude. *(Petrifications recueillies in Amerique, &c. decrites par Leopold de Buch, p.* 18. *Berlin,* 1839.) This formation is found in some places, according to the same author, nearly 13000 feet above the ocean: in others, from 3000 to 9000 feet. Hence it seems probable, that this formation gradually ascends southerly from the vicinity of New York, until south of the equator it has reached a great height. And it seems to justify the opinion of Beaumont, that this continent has experienced a sort of see-saw movement, *(mouvement de bascule,)* whereby its northeastern parts have been depressed, and its southwestern side elevated. Beaumont has founded his opinion upon the situation of the chalk and the tertiary strata in North America. But the additional facts respecting the chalk formation of the Andes, confirm and render more striking his conclusion. It is, indeed, an astonishing example of the immense scale on which subterraneous movements have taken place: and it leads us to anticipate, that when the rocks of this continent shall be fully explained, we shall have a most magnificent illustration of the geology of the globe.

## PART IV.

# ELEMENTARY GEOLOGY.

I have been often reminded that many readers of my Report on the Geology of Massachusetts, would find it convenient to have a summary of the essential principles of that science appended to it. The government have so far approved of this suggestion, as to allow me to annex the following brief outline. As I prepared it, it was much more extensive; and being a gratuitous labor on my part, I had liberty to print the whole in a separate form. This has been done: and if any readers desire a fuller account of geology than what follows, they will find it in that work; as well as in many others that have been recently published. I have made frequent reference to the most valuable of these in the following pages.

I have arranged the subject under short heads; such as *Definition*, *Principle*, *Description*, *Inference*, *Remark*, *Proof*, &c. whose abbreviations will be readily understood. This is done chiefly for the sake of brevity and definiteness. Some of the most important principles and inferences are given in larger type.

## SECTION I.—A GENERAL ACCOUNT OF THE CONSTITUTION AND STRUCTURE OF THE EARTH, AND OF THE PRINCIPLES ON WHICH ROCKS ARE CLASSIFIED.

*Definition.* Geology is the History of the mineral masses that compose the earth, and of the organic remains which they contain.

*Def.* Every part of the globe, which is not animal or vegetable, including water and air, is regarded as Mineral.

*Def.* The term Rock, in its popular acceptation, embraces only the solid parts of the globe: but in geological language, it includes also the loose materials—the soils, clays, and gravels—that cover the solid parts.

*Principle.* The form of the earth is that of a sphere, flattened at the poles: technically, an oblate spheroid. The polar diameter is about 26 miles shorter than the equatorial.

*Inference.* Hence it is inferred that the earth must have been once in a fluid state; since it has precisely the form which a fluid globe, revolving on its axis with the same velocity as the earth, would assume.

*Prin.* Taken as a whole, the earth is about five times heavier than water; or 2 1-2 times heavier than common rocks.

*Inference.* We hence learn that the density of the earth increases from the surface to the center: but it does not follow that the nature of the internal parts is different from its crust.

For in consequence of condensation by pressure, water at the depth of 362 miles, would be as heavy as quicksilver, and air as heavy as water, at 34 miles in depth: while at the center, steel would be compressed into one fourth, and stone into one eighth of its bulk at the surface. *Mrs. Somerville's Connection of the Physical Sciences.*

## *Stratification.*

*Def.* The rocks which compose the globe are divided into two great classes, the Stratified and Unstratified.

*Def.* Stratification consists of the division of a rock into regular masses, by nearly parallel planes, occasioned by a peculiar mode of deposition. Strata vary in thickness from that of paper to many yards.

*Def.* The term *Stratum* is sometimes employed to designate the whole mass of a rock, while its parallel subdivisions are called *beds* or layers. The term bed is also employed to designate a layer, whose shape may be more or less lenticular, or wedge shaped, included between the layers of a more extended rock; as a bed of gypsum, a bed of coal, a bed of iron, &c. In this case the bed is sometimes said to be subordinate.

*Def.* When beds of different rocks alternate, they are said to be interstratified.

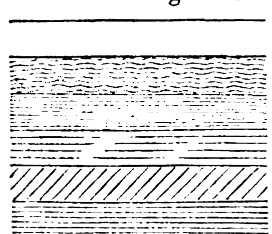
*Def.* A seam is a thin layer of rock that separates the beds or strata of another rock: Ex.gr. a seam of coal, of limestone &c. The term is also employed sometimes in this country to designate the interval or crack between two contiguous beds.

*Descrip.* A bed or stratum is often divided into thin laminæ, which bear the same relation to a single bed, as that does to the whole series of beds. This division is called the *lamination* of the bed; and always results from a mechanical mode of deposition. The appearanee of fissility which it gives to a rock, is often deceptive; since the layers separate with great difficulty. This is especially true in gneiss.

*Descrip.* The lamination is sometimes parallel to the planes of stratification; sometimes they are much inclined to each other; and often it is undulating and tortuous.

Fig. 202 shows the different kinds of lamination.

Fig. 202.

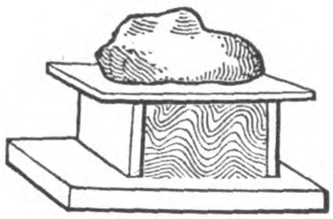



## *Origin of the varieties of Lamination.*

*Causes.* All the lamination of stratified rocks was undoubtedly produced originally by deposition in water, and the varieties have resulted from modifying circumstances. 1. The parallel laminae are the result of quiet deposition upon a level surface. 2. The waved lamination, in many instances, is nothing but *ripple marks*; such as are seen constantly upon the sand and mud at the bottom of rivers, lakes, and the ocean. In the secondary rocks this is too manifest to be mistaken. 3. The oblique lamination has generally been the result of deposition upon a steep

**shore, where the materials are driven over the edge of an inclined plane. 4. Highly contorted lamination has resulted from lateral and vertical pressure, as illustrated by Fig.. 203**

Fig. 203.




*Illus.* If pieces of cloth of different colors be placed upon a table *c*, and covered by a weight, *a*, and then lateral forces *b b*, be applied; while the weight will be somewhat raised, the cloth will be folded and contorted precisely like the laminae of many rocks; as is shown in the figure.

*Prin.* The agency of water and heat is sufficient to bring rocks, in nearly every known case, into that plastic state which is necessary to make them bend without breaking.

*Descrip.* In clay beds containing disseminated carbonate of lime, we frequently find nodules of argillo-calcareous matter, sometimes spherical, but more usually flattened. These are generally called *Claystones*, and the common impression is, that they were rounded by water. But they are unquestionably the result of molecular attraction. The slaty divisions of the clay often extend through the concretions: and on splitting them open, a leaf, or a fish, or some other organic relic, is frequently found. In New England, however, both the slaty cleavage and the organic nucleus are usually wanting.

Fig. 204, will convey an idea of the manner in which these concretions are situated in the clay.

*Descrip.* The internal parts of these concretions of limestone and hydrate of iron, often exhibit numerous cracks, which sometimes divide the matter into columnar masses, but more frequently into irregular shapes. When these cracks are filled with calcareous spar, as is often the case in calcareous concretions, they take the name of *Ludus Helmontii*, *Turtle Stones*, or more frequently of *Septaria*. From these is prepared in England the famous Roman Cement. Fig. 205, is a section of one of these.

Fig. 204.

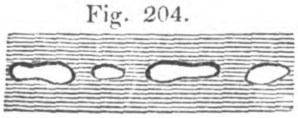
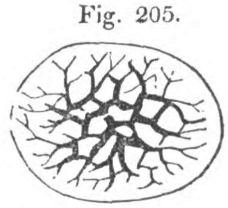


Fig. 205.



*Descrip.* Certain limestones called Oolites, are often almost entirely composed of concretions made up of concentric layers: but the spheres are rarely so large as a pea.

*Descrip.* The concretionary structure, however, often exists in limestone on a very large scale, forming spheroidal masses not only many feet, but many yards in diameter.

## *Divisional Structures.*

*Def.* Both the stratified and unstratified rocks are traversed by divisional planes called

*joints*; which divide the masses into determinate shapes, which are different from beds and their laminae. Those only which occur in the stratified rocks will be here noticed.

*Descrip.* The most important of these joints called *masterjoints*, are more or less parallel, and so extended as to imply some general cause of production.

*Descrip.* When these joints cross the beds obliquely, as they usually do, and there are two sets of them, they divide the rock into rhomboidal masses of considerable regularity; though wanting in that perfect equality in the corresponding angles of the prisms which is found in crystals of the same mineral substance.

## *Cleavage.*

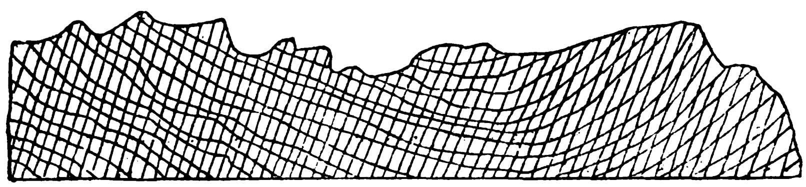
*Descrip.* Some rocks are divided by a set of parallel planes, coincident neither with the stratification, the lamination, nor the joints. These are called *cleavage planes*, because they are supposed always to result from a crystaline arrangement of the particles of the rock, superinduced after its original deposition.

*Descrip.* This cleavage is most common in argillaceous slate, and in many cases constitutes its slaty structure. But in many instances this structure is the result of original deposition, and corresponds to, or rather constitutes, the lamination. This is particularly true of the finer slates, both argillaceous, micaceous, talcose and chloritic, in this country. *Lyell's Elements of Geology, p.* 238.

*Descrip.* The cleavage planes are often inclined to the planes of stratification and lamination at an angle of 30° or 40°, and sometimes the two planes dip in opposite directions. The cleavage planes are remarkable for their almost perfect parallelism, while the strata and their laminae are usually contorted.

Fig. 206, exhibits a set of cleavage planes crossing the curved strata in the slate rocks of Wales.

Fig. 206.



*Cleavage Planes intersecting curved Strata.*

In Fig. 207, are exhibited the planes of stratification B B, B B, the joints A A, A A, and the slaty cleavage, d d.

Fig. 207.

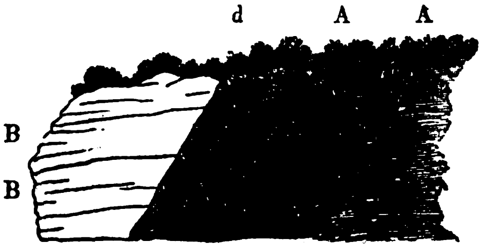
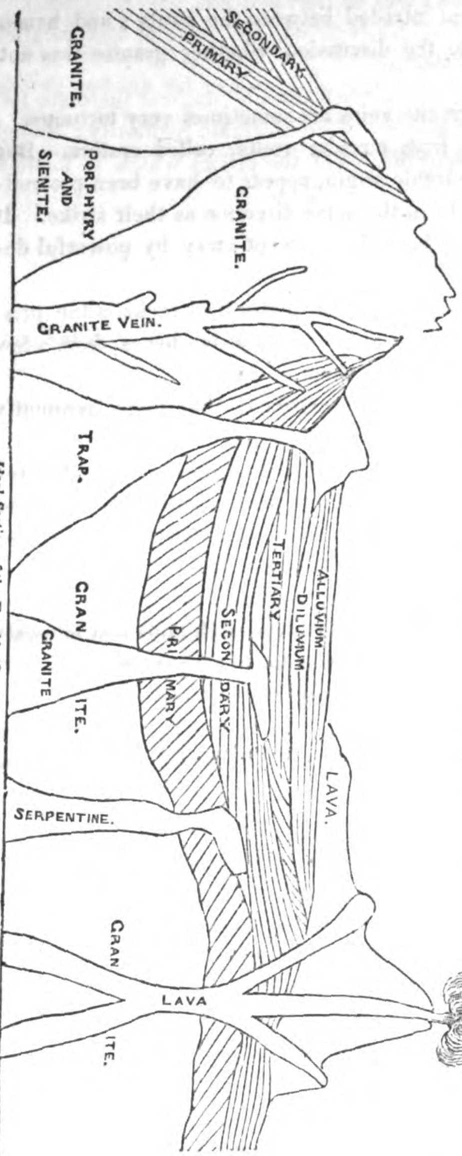


Fig. 207.




*Ideal Section of the Earth's Crust.*

**Descrip.** **The unstratified rocks occur in four modes. 1. As irregular masses beneath the stratified rocks. 2. As veins crossing both the stratified and unstratified rocks. 3. As beds or irregular masses thrust in between the strata. 4. As overlying masses. All these modes are shown in Fig. 207.**

*Def.* Veins are of two kinds: 1. Those of segregation: 2. Those of injection. The former appear to have been separated from the general mass of the rock by elective affinity, when it was in a fluid state; and consequently they are of the same age as the rock. Hence they are often called contemporaneous veins.

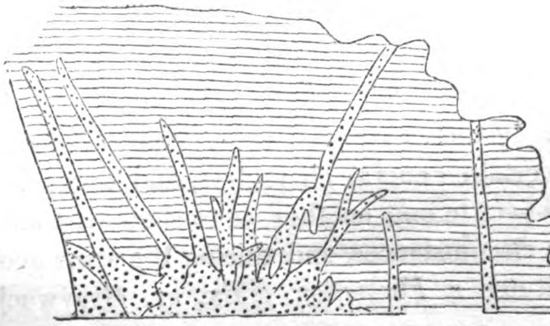
*Def.* The second class were once open fissures, which at a subsequent period, were filled by injected matter.

*Descrip.* Injected veins can often be traced to a large mass of similar rock, from which, as they proceed, they often ramify and become exceedingly fine, until they are lost. Usually, especially in the oldest rocks, they are chemically united to the walls of the containing rock; but large trap veins have often very little adhesion to the sides.

Fig. 208, exhibits granite veins protruding from a large mass of granite into hornblende slate in Cornwall.

*Def.* The large veins that are filled with trap rock, or recent lava, are usually called *dykes*. These differ from true veins, also, in rarely sending off branches.

Fig. 208.



*Granite Veins in Hornblende slate, Cornwall, Eng.*

*Descrip.* Veins and dikes usually cross the strata at various angles of obliquity. But not unfrequently, for a part of their course, they have been intruded between the strata; and hence have been mistaken for beds, and have given rise to the discussion whether granite was not stratified.

*Descrip.* Dykes are usually nearly straight; but granite veins are sometimes very tortuous.

*Descrip.* In modern volcanos the lava is ejected from circular vents, called craters. But the older unstratified rocks, although evidently of volcanic origin, appear to have been protruded along extended fissures, either across the strata, or in the same direction as their strike. It is possible, however, that craters did once exist, and have been swept away by powerful denudation of the surface.

*Def.* An interesting variety of jointed structure in some of the unstratified rocks is the prismatic or columnar, by which large masses of rocks are divided into regular forms, from a few inches to several feet in diameter; but with no space between them.

*Descrip.* The layers of the stratified rocks are sometimes horizontal; but more frequently they are tilted up, so as to dip beneath the horizon at every possible angle.

*Def.* The angle which the surface of a stratum makes with the plane of the horizon is called its *inclination or dip;* and the direction of its upturned edge is called its *strike* or *bearing.*

*Descrip.* As a general fact the newer or higher rocks are less inclined than those below. The highest are usually horizontal; while the oldest are often perpendicular.

*Descrip.* The instrument employed for ascertaining the dip of a stratum, is called a *Clinometer.* Every geologist, however, ought to be able to determine the dip with sufficient accuracy for most purposes by the eye. A good pocket compass will answer for finding the strike.

*Des.* Unstratified rocks do not probably occupy one tenth part of the earth's surface.

*Prin.* These rocks, however, we have reason to suppose, occupy the internal parts of the earth to a great depth, if not to the center; over which the stratified rocks are spread with very unequal thickness, and in many places are entirely wanting.

*Explanation.* Fig. 207, will convey a better idea than language, of the relative situation of the two classes of rocks. The different groups of stratified rocks, viz. Alluvium, Diluvium, Tertiary, Secondary and Primary, are here shown resting upon one another, and upon granite beneath. This granite, also, is shown protruding to the surface; and upon its side lie the stratified rocks highly inclined: veins of sienite, porphyry, trap, serpentine and lava, are also shown protruding through the granite, and coming from beneath it; as they must do, because they have been erupted since the granite. Veins of sienitic granite of a posterior date are likewise shown, penetrating the stratified rocks to the top of the secondary strata, which is the most recent granite yet discovered. The sienites and porphyry rise no higher than the top of the secondary: but the trap rises to the top of the tertiary; and finally, modern lava overspreads alluvium. The stratified rocks are represented as inclined at different angles; the lowest being the most tilted up. Although, therefore, this is not a section of any particular portion of the earth's crust, yet it will give a correct idea of the relative situation of the groups both of stratified and unstratified rocks. For a much larger and more detailed section of this sort, see Buckland's Bridgwater Treatise, Plate 1.

## *Formations.*

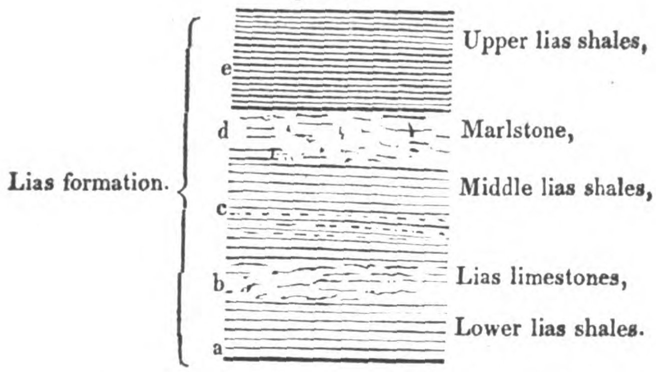
*Def.* Each rock, in its most extended sense, consists of several varieties, agreeing together in certain general characters, and occupying such a relative situation with respect to one another, as to show that all of them were formed under similar circumstances, and during the same geological period. Such a group constitutes a *Formation.* Ex. gr. Graywacke Formation, Gneiss Formation &c.

***Def.* This term often embraces several distinct rocks, when there is reason to suppose them the result of the same geological period.**

Fig. 209. will give an idea of the English Lias formation lying between the Oolite formation above, and the red sandstone formation beneath.

***Def.*** When the planes of stratification are parallel to one another in different formations, the stratification is said to be *conformable*: when not parallel it is *unconformable.*

Fig. 209.



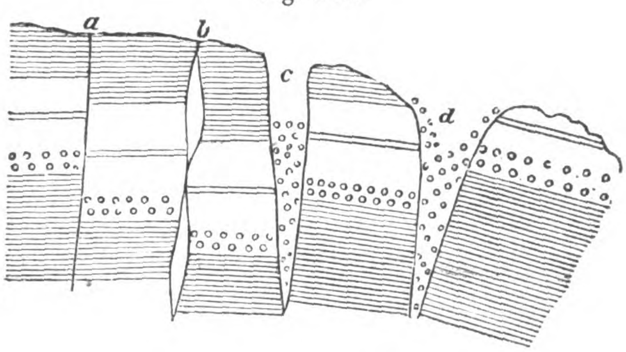

*Descrip.* The stratification in different formations is usually unconformable, as is shown in the position of the secondary and primary formations in Fig. 208.

*Inf.* It is hence inferred that the stratified rocks were elevated at different epochs: in other words, those formations which are the most highly inclined, must have been partially elevated before the others were deposited upon them.

*Descrip.* These numerous elevations of the strata have produced in them a great variety of cracks, fissures, and slides.

*Def.* When the continuity of the strata is interrupted by a fissure, so that the same stratum is higher on one side than on the other, or has been slidden laterally, that fissure is called a *fault*, or *a trouble—a slip—a dyke*, &c: as **a**, b, c, d, Fig. 210.

Fig. 210.




*Def.* If the fissure is open and of considerable width, and is succeeded at each extremity by a wider valley, it is called a *gorge*, as *c*

*Def.* If it be still wider, with the sides sloping or rounded at the bottom, a valley is produced; as *d*.

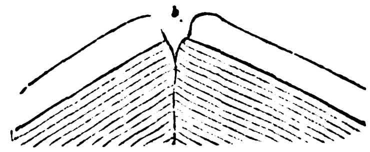
*Prin.* In a similar way most of the vallies of primitive countries, were formed.

*Def.* The line forming the top of a mountain ridge, or running through a valley, along

which the strata dip in opposite directions, is called an ***anticlinal line***, or ***anticlinal axis***: as at *a*, Fig. 211, and *b*, Fig. 212.

Fig. 211.


Fig. 212.




*Def.* When the strata dip towards this line on each side of it, it is called a ***synclinal line***, *or axis*, as at *b*, Fig. 211.

## *Classification of Rocks.*

*Descrip.* If we suppose ourselves placed in a meadow which has resulted from the successive deposits of annual floods, and begin a perpendicular excavation i. to the earth, we shall pass through the different classes of rocks in the following order.

*Def.* For a few feet only—rarely as many as 100, we shall pass through layers of loam, sand, and fine gravel, arranged in nearly horizontal beds. This deposit, from an existing river, is denominated ***Alluvium***.

*Def.* All deposits from causes now in action, which have taken place since the present order of things commenced on the globe, are usually regarded as alluvial.

*Def.* The second formation which we shall penetrate, is composed of coarse sand and gravel, with fine sand and even sometimes clay, containing, however, lage rounded masses of rock called Bowlders; the whole mixed together, yet often distinctly and horizontally stratified. This formation, evidently the result of powerful currents of water, is called ***Drift*** or ***Diluvium***. It is distinguished from alluvium, first by its inferior position; secondly, by the marks of a more powerful aqueous agency; and thirdly, by extending over regions where no existing streams or other causes now in action could have produced it.

*Obs.* Some geological writers do not admit the existence of Diluvium as a distinct formation, but include it all in the formations above or beneath. *See Lyell's Principles of Geology, passim.*

*Def.* The third series of strata which we penetrate in descending into the earth, is composed of layers of clay, sand, gravel, and marl, with occasional quartzose and calcareous beds more or less consolidated; all of which were deposited in waters comparatively quiet and in separate basins. They also contain many peculiar organic remains, and sometimes dip at a small angle, though usually they are horizontal. These strata are called ***Tertiary***.

*Def.* The formations which we penetrate after passing through the tertiary, are composed for the most part of solid rocks. They are, however, mostly made up of sand, clay, and pebbles, bound together by some sort of cement. With these are interstratified many varieties of limestone; and throughout the whole series is found a great variety of the remains of animals and plants, very different from those in the tertiary strata. These groups of rocks sometimes lie horizontal; but are usually more or less elevated, so as to make them dip at various angles. They are called ***Secondary Rocks***.

*Obs.* It will be seen that all the fossiliferous rocks below the tertiary are here included in the secondary class. Many geologists, even to the present time, have separated some of the lower groups into a class named *Transition*, because they appear as if produced when the earth was in a transition state from desolation to a habitable condition, and have a texture partly mechanical and partly chemical. I do not attempt to define such a class, because I cannot fix upon any characters by which it can be distinguished from the secondary strata.

*Def.* The stratified rocks below the secondary, are distinguished by the absence of organic remains, by having a structure more or less crystaline, and by being more highly inclined. They are called ***Primary Rocks***.

*Remark.* D'Halloy, Dr. Macculloch, Prof. Phillips, and some others include some of the fosiliferous rocks—as clay slate and graywacke, in the Primary Class, as may be seen on the Tabular View at the end of this Section.

*Descrip.* Immediately beneath the primary stratified rocks, we find the unstratified ones.

*Inf.* As this is found to be the case wherever the stratified rocks have been penetrated, it is inferred that the internal parts of the globe, beneath a comparatively thin crust, are made up of unstratified rocks: at least to a very great depth.

*Descrip.* Among the primary rocks there is no settled order of superposition. Perhaps gneiss most commonly lies immediately above granite; but the other members of the series are frequently found also in the same position.

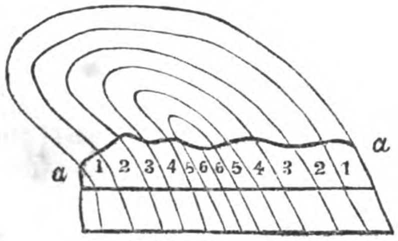
*Descrip.* Among the fossiliferous rocks there exists an invariable order of superposition.

*Exception.* 1. In a few cases internal forces have not merely lifted upon their edges, but actually overturned strata of considerable thickness. The section in Fig. 211, was taken in the Alps, and exhibits a case of this kind. G, is gneiss, L, L, limestone, C, conglomerate, locally called *Naglefluh.* Now the limestone is really an older rock than the conglomerate; and yet it lies above the conglomerate, because the whole series has been tossed over, so as to bring the newer rock beneath the older. The supposed case of this sort in Hoosac Mountain, has already been described, on page 577.

*Descrip.* In some instances the strata have been folded together on a vast scale, and in such a manner as to bring some of the newer rocks beneath the older. Fig. 213, is a section of this character. Originally the strata were probably folded, as is shown by the curved lines passing from 1 to 1, 2 to 2, and so on. But their upper parts have been denuded, so that the present surface is a, a. The oldest strata are now found to be 6, 6; and they correspond outward on each side of these; as 5, 5; 4, 4; &c. Such an example as this has been called a *folded axis.*

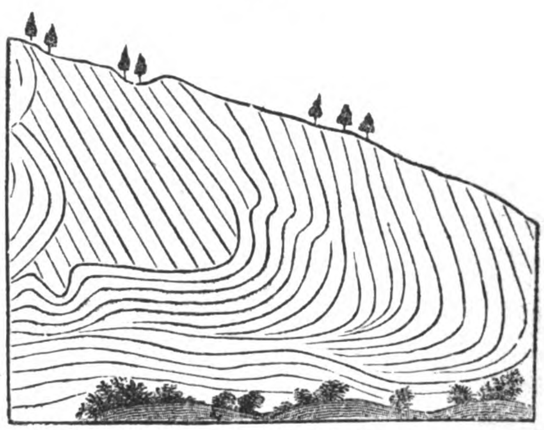
*Descrip.* Sometimes the strata, after descending in this inverted manner from 1000 to 1500 feet, curve in such a direction as to bring them into their proper position: as is shown in Fig. 214, taken in the Alps.

Fig. 213.




*Folded Axes.*

Fig. 214.

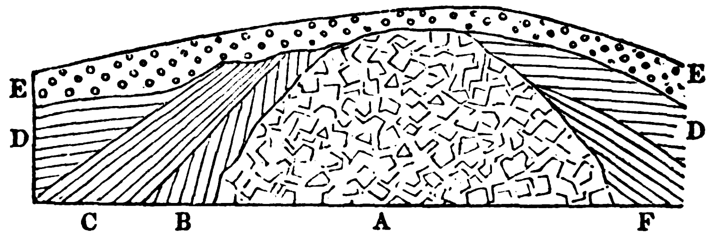


*Curved Strata in the Alps.*

*Descrip.* One or more rocks are frequently wanting in the secondary series, which brings those of very different ages into contact: but the order of arrangement is never thereby disturbed.

*Examples.* Thus in Fig. 215, on the left side of the central mass of granite; A, we have the primary, B, secondary, C, and tertiary, D, in regular order: but on the other side, the secondary is wanting, and the tertiary, D, lies directly upon the primary, F, as well as upon the granite, while a deposit of diluvium, E, comes in contact with all.

Fig. 215.




## *Tabular View of the Stratified Rocks.*

*Rem.* The following Table affords a synoptical view of most of the Systems of Classification that have now been described. It should be recollected that these Systems have been mostly derived from the study of the rocks of Great Britain, and a part of the Continent of Europe. But in all their great outlines they are found to apply almost equally well to all other parts of the globe hitherto examined. This Table embraces only the stratified rocks. The unstratified class will receive more attention in a subsequent Section.

*Inf.* From a careful examination of the following Table it appears that in all the essential principles of the classification of rocks, geologists are nearly agreed. They all admit one class to be stratified, and another unstratified :—one portion of the stratified rocks to be fossiliferous and another portion not fossiliferous. And they generally agree, also, as to the extent of the different distinct formations: although some would make their number greater than others—just as it is in respect to species in mineralogy, botany, and zoology. Now these three principles are all that are essential for classification; and some of the best geologists, as may be seen by the Table, limit themselves to these. But if others choose to subdivide the formations still farther, and to refer the groups to primary, secondary, &c. classes, even though they differ widely here, it must not be hence inferred that they are at variance in respect to the essential principles of classification.

## VARIOUS CLASSIFICATIO

| *Principal Groups of Rocks.* | *Thickness in feet in G. B.* | *Improved Wernerian.* | *Macculloch's 1831.* | *Conybeare's. 1822.* | *Brongniart's 1829.* | | *Omalius d' Halloy's 1831.* | | *De La Beche's 1833.* | |
|---|---|---|---|---|---|---|---|---|---|---|
| Alluvium. | | Alluvium. | Alluvial. | Superior Order. | Alluvial and Lysian. | | Modern. | Secondary Class. | Modern Group. | |
| Diluvium. | | Diluvium. | | | Clysmian. | Saturnian Period. | Tertiary Groups. | | Erratic Block Group. | |
| Tertiary Strata. | 1350 | Tertiary. | | | Izenian Rocks. | | | | Supercretaceous Group. | |
| Chalk. | 600 | Secondary. | Secondary. | Supermedial Order. | | | Ammonean Groups. | | Cretaceous Group. | |
| Green Sand. | 480 | | | | | | | | | |
| Wealden. | 900 | | | | | | | | | |
| Oolitic System. | 1230 | | | | | | | | Oolitic Group. | |
| Lias. | 1050 | | | | | | | | | |
| New Red Sandstone. | 1200 | | | | | | | | Red Sandstone Group. | V M Re |
| Coal Formation. | 3000 | | | Medial Order. | | | Hemilysian Groups. | Primordial Class. | Carboniferous Group. | |
| Carboniferous Limestone. | 2700 | | | | | | | | | |
| Old Red Sandstone. | 5100 | | | | | | | | | Old |
| Silurian System. | 7500 | Transition. | Primary. | Submedial Order. | Hemilisyan. | | | | Graywacke Group. | T C G Tr I T |
| Cambrian or Graywacke System. | Unknown | | | | | | | | Lowest fossiliferous Group. | |
| Clay Slate. | Unk | Primitive or Primary. | | Inferior Order. | Agalysian Rocks. | | | | Inferior Stratified Non-fossiliferous | |
| Quartz Rock. | Unk | | | | | | | | | |
| Hornblende Slate. | Unk | | | | | | | | | Ho |
| Talcose Slate. | Unk | | | | | | | | | |
| Primary Limestone. | Unk | | | | | | | | | Pri |
| Serpentine. | Unk | | | | | | | | | |
| Mica Slate. | Unk | | | | | | | | | |
| **Gneiss.** | **Unk** | | | | | | | | | |

## SECTION II.—THE CHEMISTRY AND MINERALOGY OF GEOLOGY.

*Descrip.* Of the fifty-four simple substances hitherto discovered, sixteen constitute by their various combinations, nearly the whole of the matter yet known to enter into the composition of the globe. They are as follows, arranged in three classes, according to their amount; the first in each class being most abundant.

### 1. *Metalloids, the bases of the earths and alkalies.*

1. Silicium. 2. Aluminium. 3. Potassium. 4. Sodium. 5. Magnesium. 6. Calcium.

### 2. *Metals Proper.*

1. Iron. 2. Manganese.

### 3. *Non Metallic Substances.*

1. Oxygen. 2. Hydrogen. 3. Nitrogen. 4. Carbon. 5. Sulphur. 6. Chlorine. 7. Fluorine. 8. Phosphorus. *De la Beche's Researches in Theoretical Geology, p.* 22. *Amherst,* 1837.

*Descrip.* The metallic substances mentioned above, united with oxygen, constitute the great mass of the rocks, consolidated and unconsolidated, accessible to man. Oxygen also forms twenty per cent of the atmosphere, and one third part by measure of water. Hydrogen forms the other two thirds of this latter substance; and it is evolved also from volcanos, and is known to exist in coal. Nitrogen forms four fifths of the atmosphere, and enters into the composition of animals, living and fossil. It is found also in coal. Carbon, however, forms the principal part of coal; and it exists likewise in the form of carbonic acid in the atmosphere, though in a less proportion than one per cent; and it forms an important part of all the carbonates, and is produced wherever vegetable and animal matters are undergoing decomposition. Sulphur is found chiefly in the sulphurets and sulphates that are so widely disseminated. Chlorine is found chiefly in the ocean, and in the rock salt dug out of the earth. Fluorine occurs in most of the rocks, though in small proportion. Still less is the amount of phosphorus, though widely diffused in the rocks and soils, and abundant in organic remains.

*Descrip.* Nearly all the simple substances above mentioned have entered into their present combinations as binary compounds: that is, they were united, two and two, before forming the present compounds in which they are found. The following constitute nearly the whole binary compounds of the accessible parts of the globe.

1. Silica. 2. Alumina. 3. Lime. 4. Magnesia. 5. Potassa. 6. Soda. 7. Oxide of Iron. 8. Oxide of Manganese. 9. Water. 10. Carbonic Acid.

*Obs.* It is meant only that these binary compounds, and the sixteen simple substances that have been enumerated, constitute the largest part of the known mass of the globe: for many other binary compounds and probably all the known simple substances are found in small quantity in the rocks; but not enough to be of importance in a geological point of view.

*Descrip.* It has been calculated that oxygen constitutes 50 per cent of the ponderable matter of the globe, and that its crust contains 45 per cent of silica, and at least 10 per cent of alumina. Potassa constitutes nearly 7 per cent. of the unstratified rocks, and enters largely into

the composition of some of the stratified class. Soda forms nearly six per cent, of some basalts and other less extensive unstratified rocks; and it enters largely into the composition of the ocean. Lime and Magnesia are diffused almost universally among the rocks in the form of silicates and carbonates—the carbonate of lime having been estimated to form one seventh of the crust of the globe. At least three per cent. of all known rocks are some binary combination of iron, such as an oxide, a sulphuret, a carburet, &c. Manganese is widely diffused, but forms much less than one per cent. of the mass of rocks.

*Descrip.* Eight or nine simple minerals constitute the great mass of all known rocks: These are 1 Quartz, 2 Feldspar, 3 Mica, 4 Hornblende, 5 Carbonate of Lime, 6 Talc, embracing chlorite and soapstone, 7 Augite, 8 Serpentine. Oxide of iron is also very common; but it does not usually show itself till the decomposition of the rock commences.

*Descrip* Water constitutes a part of nearly all rocks; but in most cases it appears to be mechanically combined; for with one or two exceptions, it does not exist in the simple minerals that enter into the composition of rocks.

## *Geological Situation of useful Rocks and Minerals.*

*Prin.* The rocks and minerals useful in an economical point of view, are in a few instances found in almost every part of the rock series: but in a majority of cases, they are confined to one or more places in that series.

### *Examples.*

*Marl,* or a mixture of carbonate of lime and clay, is confined to the alluvial and tertiary strata: and differs from many varieties of limestone, only in not being consolidated.

*Limestone,* from which every variety of Marble, one variety of alabaster, and every sort of quicklime are obtained, is found in almost every rock, stratified and unstratified, below diluvium. In the oldest stratified rocks and in the unstratified, it is highly crystaline; and in the newest strata (ex. gr. chalk) it is often not at all crystaline. The most esteemed marbles are obtained from the newer primary and older secondary strata.

*Sulphate of Lime, or Gypsum,* which produces one variety of alabaster, and is employed for taking casts, forming hard mortar, and spreading upon land in the state of powder, occurs chiefly in the new red sandstone series. It is found also in the Lias, Oolite, Green Sand, and Tertiary strata. In this country it is found associated with the oldest of the secondary (transition) rocks.

*Rock Salt,* (Chloride of Sodium) is frequently found associated with gypsum in the new red sandstone. It occurs also in the supercretaceous or tertiary strata; as in Sicily: at the celebrated deposit at Wieliczka in Poland, at Zipaquira in South America; and Cardona, in Spain, in cretaceous strata: in the Tyrol, in the Oolites; and in Durham, in England, salt springs occur in the coal formation. In this country they proceed from still older rocks. *Buckland's Bridgewater Treatise, Vol. 1. p. 72. De la Beche's Manual, p.* 246

*Descrip.* If vegetable matter be exposed to a certain degree of moisture and temperature, it is decomposed into the substance called *Peat,* which is dug from swamps, and belongs to the alluvial formation.

*Lignite or Brown Coal,* the most perfect variety of which is jet, is found chiefly in the tertiary strata; sometimes in the higher secondary; and appears to be peat which has long been buried in the earth, and has undergone certain chemical changes, whereby bitumen has been produced. It generally exhibits the vegetable structure.

*Bituminous Coal* appears to be the same substance which has been longer buried in the earth, and has undergone still farther changes; though their precise nature is not well known. *Its*

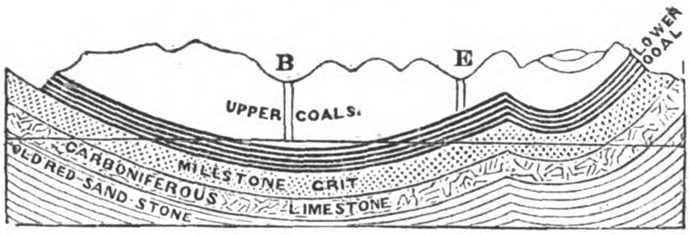
principal deposit is in that part of the secondary series called the coal formation, or coal measures. But it occurs in small quantity in the New Red Sandstone series, in England, Poland, and Massachusetts: and in Scotland it is worked in the lias limestone. A thick bed of it has also been found in the Plastic Clay of the Tertiary strata in Hesse. *Prof. Conybeare's Report* (1832) *on Geology to the British Association, p.* 390. *Also, Philosophical Magazine, Vol.* 2. *New Series, p.* 101 *and* 108.

The principal deposit of anthracite in Europe, is in the graywacke formation; and it is supposed that this substance is common coal which has undergone still farther changes and lost its bitumen. In this country, however, there is reason to suppose that the vast deposit of anthracite in Pennsylvania, the largest in the world, is associated with the common coal measures. *See Prof. H. D. Roger's Second Annual Report on the Geological Exploration of the State of Pennsylvania*, 1838.

*Graphite, Plumbago, or Black Lead,* appears to be anthracite which has undergone still farther mineralization: at least, in some instances, when coal has been found contiguous to igneous rocks, it is often converted into plumbago; and hence such may have been the origin of the whole of it. In the Alps plumbago is found in a clay slate that lies above the lias. *(Annales des Sciences Naturelles, Tome XV.* 1828. *p.* 377.) It is found also in the coal formation. *Traite Elementaire de Mineralogie par F. S. Beudant, Tome* 2. *p* 263.

*Descrip.* All the varieties of coal that have been described, occur in the form of seams, or beds, interstratified with sandstones and shales; and most usually there are several seams of coal with rocks between them; the whole being arranged in the form of a basin. Fig. 216 is a sketch of the great coal basin of South Wales, in Great Britian; which contains twenty three beds of coal; whose united thickness is ninety three feet. When we consider how much this arrangement facilitates the exploration and working of coal, we can hardly doubt but it is the result of Divine Benevolence.

Eig. 216.




*Coal Basin of South Wales: G. Britian.*

*Descrip.* The *Diamond,* which is pure crystalized carbon, has been found associated with new red sandstone at Golconda in South America, and at Panna in India. This rock is there in proximity with, and based upon granite, and perhaps the crystalization of the carbon resulted from this cause. *Edinburgh Journal of Science, Vol. X. p.* 184. *Conybeare's Report on Geology, p.* 395 *and* 398.

In general the diamond is found in diluvium; having been washed from its original situation by water: and we may always presume that every mineral existing in the older rocks will be found also in diluvium; because their detritus must contain them.

*Inference.* It has been inferred from the preceding facts, that all the varieties of carbon above described, had their origin in vegetable matter; and that heat and water have produced all the varieties which we now find. *Macculloch's System of Geology, Vol.* 2. *p.* 297.

Almost all the precious stones, such as the sapphire, emerald, spinel, chrysoberyl, chrysoprase, topaz, iolite, garnet, tourmaline, chalcedony, amethyst, &c. are found exclusively in the

oldest and most crystaline rocks. Quartz, in the various forms of rock crystal, chalcedony, carnelian, cacholong, sardonyx, jasper, &c. is found sometimes in the secondary strata, and especially in the trap rocks, associated with the secondary formations.

*Descrip.* Some of the metals, as platinum, gold, silver, mercury, copper, bismuth, &c. exist in the rocks in a pure, that is, a metallic state; but usually they occur in the state of oxides, sulphurets, and carbonates, and are called ores. It is rare that any other ore is found in sufficient quantity to be an object of exploration on a large scale.

*Descrip.* These ores occur in four modes: 1. In regular interstratified layers, or beds: 2. In veins or fissures, crossing the strata and filled with ore united to some gangue or matrix. 3. In irregular masses: 4. Disseminated in small fragments through the rocks.

*Descrip.* Iron is the only metal that is found in all the formations in a workable quantity. Among all its ores, only four are wrought for obtaining the metal: viz. the magnetic oxide, the specular or peroxide, the hydrated peroxide, and the protocarbonate.

Manganese occurs in the state of a peroxide and a hydrate; and is confined to the primary rocks; except an unimportant ore called the earthy oxide, which exists in earthy deposits.

The most important ores of copper are pyritous copper and the carbonates. These are found in the primary rocks, and as high in the secondary series as the new red sandstone; in one instance in tertiary strata. *Wonders of Geology, Vol. 2. p.* 651.

The only ore of lead of much importance is the sulphuret. This generally occurs in the primary rocks, both stratified and unstratified; but it exists also in the newer rocks as high in the series as the lias.

The deutoxide of tin is the principal ore of that metal. This is most commonly found in the oldest formations of gneiss, granite, and porphyry: also in the porphyries connected with red sandstone. It is found likewise in quantity sufficient to be wrought in diluvium.

Of zinc the most abundant ore is the sulphuret, which is commonly associated with the sulphuret of lead, or galena. Other valuable ores are the carbonate, silicate, and the oxide, which occur in secondary rocks.

The most common ore of antimony, the sulphuret, has hitherto been found chiefly in granite, gneiss, and mica slate.

The principal ore of mercury, the sulphuret, occurs chiefly in new red sandstone: sometimes in a sort of mica slate.

Silver, in its three forms of a sulphuret, a sulphuret of silver and antimony, and a chloride, has been found mostly in primary and transition slates:—sometimes in a member of the new red sandstone series; and in one instance in tertiary strata. *Wonders of Geology, Vol. 2. p* 651.

Gold and platinum always occur in a metallic state; and they have usually been explored in diluvium. They are often associated, however, with the older rocks; and in this country especially, a gold deposit has been traced from Canada to the southern part of Georgia, and the metal is embraced in the talcose slate formation, in veins, usually of quartz. It is found also rarely in graywacke, and even in tertiary strata.

Cobalt, bismuth, arsenic, &c. are usually found associated with silver, or copper; and of course occur in the older rocks. The other metals, which, on account of their small economical value and minute quantity, it is unnecessary to particularize, are also found in the older strata; frequently only disseminated, or in small insulated masses.

*Inf.* It appears from the facts that have been detailed respecting the situation of the useful minerals, that great assistance in searching for them may be derived from a knowledge of rocks and their order of superposition.

*Caution.* It ought not to be inferred from all that has been said, that because a mineral substance has been found in only one rock, it exists in no other. But in many cases we may be almost certain that such and such rocks cannot contain such and such minerals. Of such cases,

however, the practised geologist can alone judge with much correctness, and hence the importance of an extensive acquaintance with geology in the community. An amount of money much greater than is generally known, has been expended in vain for the want of this knowledge.

## Section III.—The Lithological Characters of the Stratified Rocks.

***Def.*** **The Lithological character of a rock embraces its mineral composition and structure as well as its external aspect, in distinction from its zoological and botanical characters, which refer to its organic remains.**

### 1. *Alluvium.*

*Descrip.* The following stratified deposits are the result of alluvial agency.

1. Soil.
2. Sand.
3. Peat.
4. Marl.
5. Calcareous Tufa or Travertin.
6. Coral Reefs.
7. Siliceous Sinter.
8. Siliceous Marl, or Deposits of the skeletons of Infusoria.
9. Bitumen.
10. Sulphate of Lime.
11. Hydrate of Iron.
12. Hydrate of Manganese.
13. Chloride of Sodium (Sea Salt.)
14. Sandstones, Conglomerates, and Breccias.

*Prin.* Soil is disintegrated and decomposed rock, with such a mixture of vegetable and animal matter that plants will grow in it.

*Descrip.* Vast accumulations of sand, the result of alluvial agency, occur not merely in the bed of the ocean and in lakes, but also upon the dry land, where they are called *dunes* or *downs.* These are composed almost entirely of silica; and being destitute of organic matter, cannot retain vegetation.

*Descrip.* The manner in which peat is formed has already been explained in general terms. (Section II.) When perfectly formed, it is destitute of a fibrous structure, and is, when wet, a fine black mud: and when dry, a powder. It consists chiefly of the substance called *geine;* a part of which is soluble, and a part insoluble in water. These deposits of peat are sometimes 30 or 40 feet thick; but they are not formed in tropical climates, on account of the too rapid decomposition of the organic matter.

*Descrip. Alluvial Marl* is usually a fine powder, consisting of carbonate of lime, clay, and soluble and insoluble geine; and is found usually beneath peat in limestone countries: sometimes at the bottom of ponds. It is produced partly by the decay of the shells of molluscous animals, and partly by the deposition of the carbonate of lime from solution in water. It contains numerous small fresh water shells, and has received the name of *shell marl.*

*Descrip. Calcareous Tufa or Travertin,* is a deposit of carbonate of lime, made by springs containing that substance in solution. It forms a solid limestone, sometimes even crystaline, and of considerable extent; so as to be used for architectural purposes. Thermal waters produce it most abundantly, as in central France, Hungary, Tuscany, and Campagna di Roma: but it is also deposited by springs of the ordinary temperature, as at Saratoga and in the Appenines. Very similar are the concreted calcareous deposits formed in caverns; those depending from the roof are called *Stalactites,* and those on the floor, *Stalagmites.*

*Descrip. Coral Reefs* are extensive deposits of carbonate of lime, formed by myriads of polyparia, or radiated animals, in shallow water, in the tropical seas. They form the habitations of these animals; and of course are organic in their structure.

*Descrip. Siliceous Sinter, or Tufa* is a deposit of silica, made by the water of thermal springs, which sometimes hold that earth in solution. Successive layers of sinter and clay frequently

occur, and these are sometimes broken up and re-cemented so as to form a breccia. *Prof. J. W. Webster in the Edinburgh Philosophical Journal. Vol. VI.*

*Descrip. Siliceous Marl, or the fossil Shields of Infusoria.* Beneath the beds of peat and mud in the primary regions of this country, a deposit often occurs, from a few inches to several feet thick, which almost exactly resembles the calcareous marl that is found in the same situation. When pure, it is white and nearly as light as the carbonate of magnesia : but it is usually more or less mixed with clay. It is found by analysis to be nearly pure *silica* ; and it turns out to be almost entirely composed of the siliceous shields, or skeletons, of those microscopic animals called *Infusoria* or *Animalculæ*, which have lived and died in countless numbers in the ponds at the bottom of which this substance has been deposited.

*Descrip.* Some springs deposit large quantities of bitumen in the form of naptha and asphaltum. Their localities and extent will be described in a subsequent Section.

*Descrip.* Although sulphate of lime very generally exists in the waters of springs, yet it is rarely deposited. One or two examples only are mentioned, where a deposit of this salt has been made ; as at the baths of San Philippo in France. *De la Beche's Manual, p.* 158.

*Descrip.* Hydrate of Iron or Bog ore is a common and abundant deposit from waters that are capable of holding it in solution : and it appears also, that this ore is often made up of the shields of Infusoria, which are often ferruginous. *Wonders of Geology, Vol.* 2 *p.* 660.

*Descrip.* The Hydrate of Manganese also, by a somewhat similar process, is frequently deposited in the form of the earthy oxide, or *Wad*, in low grounds : and it can hardly be doubted but it is an alluvial product.

*Descrip.* Chloride of Sodium or Rock Salt, is very rarely deposited from its solution in water so as to be visible, though some have supposed that this deposition does take place extensively at the bottom of such seas as the Mediterranean. It is said, however, to accumulate in some of the cavities of the rocks along the shores of the Mediterranean, in such quantity as to be collected by the inhabitants.

*Descrip. Alluvial Sandstone, Conglomerate, and Breccia*, are formed by the cementation of sand, rounded pebbles, or angular fragments, by iron, or carbonate of lime, which is infiltrated through the mass in a state of solution. They are not very common, nor on a very extended scale.

*Def.* When sand is cemented, the solid mass is called *Sandstone :* rounded pebbles produce a *Conglomerate* or *Plum Pudding Stone ;* and angular fragments, a *Breccia.*

*Def.* The varieties of alluvium, that have been described may be regarded as a Formation in the geological sense : and the period during which such a group is in the progress of deposition, that is, until some important change takes place in the material or mode of production, is called a *Geological Period :* and the point of time when the change occurs, is called an *Epoch.*

## 2. *Diluvium or Drift.*

*Descrip.* The great mass of diluvium is composed of sand and gravel of different degrees of comminution, mixed together just in the manner that violent currents of water would do it. This gravel is often not derived form the rocks beneath it, but from those at a distance of several miles, and in this country usually from ledges which lie in a northwesterly direction. The surface of this gravel is often scooped out into deep basin shaped depressions, and raised into corresponding elevations, the difference of level being sometimes 20 or 30 and even 100 or 200 feet.

*Descrip.* Scattered through this gravel, are rounded masses of rock, larger than pebbles, which are called *bowlders ;* and as they are frequently found at a great distance from the place of their origin, they are also denominated *erratic blocks*, and *lost rocks.* Oftentimes alluvial agency has removed the sand and gravel from these bowlders, so that they lie insulated upon the surface.

*Def.* When they happen to be thus insulated upon other rocks, and so poised that a small force will

make them oscillate, they are called *Rocking Stones*, several sketches of which have been given in the Third Part of this Report.

*Descrip.* Many of the most valuable of the precious stones and metals are found in diluvium; such as the diamond, the sapphire, the topaz, the ruby, and the zircon; as well as platinum, gold, and tin. Platinum, gold, and the diamond are explored almost exclusively in this formation. *Tableaux des Terrains*, p. 115.

## 3. *Tertiary Strata.*

*Descrip.* The tertiary rocks have been divided into four distinct groups of marine strata, distinguished by important peculiarities in their organic remains, and separated from one another, by strata which contain fresh water and terrestrial remains. *Buckland's Bridgwater Treatise*, *Vol.* 1. *p.* 76.

*Descrip.* Mr. Lyell has divided these strata into four groups, to which he gives the names *Eocene*, *Miocene*, *and Older and Newer Pliocene.* In the first, the number of shells identical with living species is very small, only 3 1-2 per cent. In the second group, reckoning upwards, it is 17 per cent: in the Older Pliocene, 35 to 50 per cent. and in the Newer Pliocene, 90 to 95 per cent. And by this character are the groups distinguished. *Lyell's Elements of Geology*, *p.* 284. Other geologists object to these characters as too indefinite. *De la Beche's Theoretical Geology*, *Chap. XVII. Phillips Treatise on Geology*, *p.* 180.

*Descrip.* The tertiary rocks are in general distinctly stratified, and the strata are usually horizontal. In some cases, however, (as in the Isle of Wight and at Gay Head,) they are inclined at a large angle.

*Prin.* All the stratified rocks appear to have been originally deposited from water.

*Descrip.* Rocks are deposited by water in two modes: first, as mere sediment, by its mechanical agency, in connection with gravity: secondly, as chemical precipitates from solution.

*Def.* The first kind of rocks is called *mechanical or sedimentary* rocks; the second kind, *chemical deposits.*

*Descrip.* As a general fact, the lower we descend into the rock series, we meet with less and less of a mechanical and more and more of a chemical agency in their production. The primary stratified rocks have generally been regarded as destitute of every mark of a mechanical origin except their parallel arrangement; but in fact, the greater part of them are made up of the fragments of crystals more or less worn and cemented together.

*Descrip.* In the fossiliferous rocks we sometimes find an alternation of mechanical and chemical deposits: but for the most part, these rocks exhibit evidence of both modes of deposit, acting simultaneously.

*Descrip.* In the tertiary rocks a mechanical agency decidedly predominates: nevertheless, several beds are the result of chemical precipitation; as gypsum, limestone, and rock salt.

*Descrip.* The varieties of rock composing the tertiary strata are concreted, tufaceous, argillaceous, and siliceous; or limestone, marl, plastic clay, siliceous and calcareous sands, green sand, gypsum, lignite, rock salt, and buhrstone.

## 4. *Secondary Rocks.*

*Def.* Under *Secondary Rocks*, I include all the fossiliferous strata below the Tertiary: that is, I embrace under Secondary, all those denominated by many writers Secondary and Transition.

## 1. *Cretaceous System.*

*Descrip.* In Europe this formation is usually characterized by the presence of chalk in the upper part, and sands and sandstones in the lower: In this country chalk is wanting: yet our geologists suppose that the ferruginous sand formation is the equivalent of the chalk formation of Europe. *Dr. Morton in Journal of Academy of Natural Sciences, Vol. VI. Also American Journal of Science, Vol. XVII. p.* 274. *and XVIII. p.* 243. *and XXIV. p.* 128.

*Descrip.* The Cretaceous system is thus arranged by Dr. Fitton:

Chalk. { Upper, Lower, Marly.

Green Sand. { Upper Green Sand, Gault, Lower Green Sand.

Wealden. { Weald Clay, Hastings Sands, Purbeck Strata.

***Observations on some of the Strata between the Chalk and Oxford Oolite in the South East of England, By W. H. Fitton. p.*** 105, ***London,*** 1836.

*Descrip.* Chalk is a pulverulent carbonate of lime, and its varieties have resulted from the impurities that were deposited with it. The upper beds are remarkable for the great quantity of flints dispersed through them, generally in parallel position.

*Descrip.* *Green Sand* is a mixture of arenaceous matter, with a peculiar green substance greatly resembling chlorite, or green earth.

*Descrip.* *The Wealden Formation*, which has been found in the Southeast of England, chiefly in the *wealds* or woods of Sussex and Kent, is composed of beds of limestone, conglomerate, sandstone, and clay, which abound in the remains of fresh water and terrestial animals, and appear to have been deposited in an estuary that once occupied that part of England. Similar beds occur in Scotland and in a few places on the European Continent.

## 2. *Oolitic System.*

*Descrip.* In many of the rocks of this series, small calcareous globules are imbedded, which resemble the roe of a fish, and hence such rock is called Roestone or Oolite. But this structure extends through only a small part of this formation, and it occurs also in other rocks.

*Descrip.* The Oolitic series consists of interstratified layers of clay, sandstone, marl, and limestone. The upper portion, or that which is Oolite proper, is divided into three systems or groups, called the Upper, Middle, and Lower, separated by clay or marl deposits.

*Descrip.* The lowest member of the oolitic group is called *Lias*, and consists essentially of argillaceous limestone.

*Remark.* The oolitic group is remarkable for the vast amount of calcareous matter which it contains, and for the great number and variety of its organic remains. It has not been found in America.

## 3. *Saliferous System.*

*Descrip.* In Europe writers enumerate five varieties of this group. 1. *Variegated Marl*, composed of indurated clays of various colors, among which red predominates: sometimes the clay is black, sometimes bluish gray; and gray sandstone and yellowish magnesian limestone are interstratified, the whole forming the highest member of the series. 2. ***Muschelkalk***, a gray-compact limestone, occasionally dolomitic, lying beneath the marls and not yet detected except

on the continent of Europe. 3. *Red or Variegated Sandstone.* Its varieties of color are red, blue, and green. Its composition is chiefly siliceous and argillaceous, with occasional beds of gypsum, and rock salt. (*New Red Sandstone*, English Writers. *Gres Bigarre*, French. *Bunter Sandstein German.*) 4. *Zechstein.* This consists of different varieties of limestone ; among which is fetid limestone, friable marl, and copper slate. 5. *New Red Conglomerate : Exeter Red Conglomerate.* A series of conglomerates and sandstones lying beneath zechstein, and above the coal measures : the fragments having been derived from the latter. (*Todtliegends, Rothe Todte Liegende Ger.*)

## 4. *Carboniferous System.*

*Descrip.* This group embraces three extensive deposits, resting upon one another in the following order ; beginning with the uppermost. 1. *Coal Measures.* These consist of irregularly interstratified beds of sandstone, shale and coal. Frequently these are deposited in basin-shaped cavities ; but not always. These rocks abound in faults produced by igneous agency ; whereby the continuity of the beds of coal is interrupted, and the difficulty of exploring for coal, increased in some respects ; but in other respects facilitated ; so that upon the whole, faults are decidedly beneficial. 2. *Carboniferous Limestone.* A gray compact limestone, traversed by veins of calcareous spar, and frequently abounding in organic remains. Encrinites are sometimes so abundant that the rock is called *Encrinal Limestone.* It is also called *Mountain Limestone*, and *Metaliferous Limestone*, as it abounds in lead ore. 3. *Old Red Sandstone.* This rock is composed mostly of conglomerate, but sometimes it becomes fine enough to be schistose : Its prevailing color is red, and its thickness very variable.

*Rem.* The Coal Measures exist in almost every country of much extent, and form one of the most important sources of national wealth and happiness. In England not less than 6.000.000 tons of coal are yearly raised from the mines of Northumberland and Durham : at which rate they will be exhausted in about 250 years. In South Wales, however, is a coal field of 1200 square miles, with 23 beds, whose total thickness is 95 feet ; and this will supply coal for 2000 years more. (*Bakewell's Geology, p.* 125.) In Great Britian about 15.000 steam engines are in operation by the use of coal with a power equal to that of about 2.000.000 of men. The machinery moved by this power has been supposed equivalent to that of between 300.000.000 and 400.000.000 men by direct labor. Well may Dr. Buckland say, " we are almost astounded at the influence of coal and iron and steam upon the fate and fortunes of the human race." *Bridgewater Treatise, vol.* 1. *p.* 535.

Probably no part of the world contains such immense beds of coal as the central parts of the United States. In 1837, not less than 900.000 tons of coal were carried to market from the mines in Pennsylvania alone : and the working of these mines has as yet only just commenced. The southern anthracite basin of that state is 60 miles long and two miles broad, with an aggregate thickness of 100 feet. Indeed, 30 out of the 54 counties of that state are in whole or in part based upon coal. But no one, who has not visited that state, can form any adequate idea of the quantity of coal existing there. One bed alone, which probably extends through all the anthracite region, varies from 22 to 50 feet in thickness : while the thickest bed in England is only 30 feet. *Prof H. D. Roger's Report on the Geological Exploration of the state of Pennsylvania for* 1838. *p.* 84. *Bakewell's Geology, p.* 106.

## 5. *Silurian System.*

*Descrip.* As has been stated in the first section, the Silurian System, proposed by Mr. Murchison, embraces the upper members of that extensive deposit, which has long been known un-

der the name of Graywacke Slate, or Shale Its composition is arenaceous, argillaceous, and calcareous; showing in all cases evidence of a sedimentary origin; yet having been subjected to a more powerful chemical action than the rock above it: The materials are often exceedingly fine; and then we have delicate slates; yet usually of a dull aspect. Sometimes they are very coarse, so as to form conglomerates; and these two varieties are often interstratified. The limestones bear stronger marks of a chemical than a mechanical origin, and are frequently very crystaline. Sometimes they are argillaceous, and often slaty, and frequently concretionary. They abound in organic remains, as does, in fact, the whole formation. The slates are sometimes but not extensively divided by joints and cleavage planes; though the original lamination of the beds by deposition is quite obvious.

### 6. *Clay Slate and Graywacke System* (Phillips). *Cambrian Group* (Sedgwick.)

*Descrip.* This extensive deposit, at least 3000 or 4000 yards thick in Wales, embraces the lower part of the Graywacke Group, and the clay slate of other geologists.

The whole of it is eminently argillaceous: but it varies from the finest clay to conglomerates, with fragments of quartz, feldspar, mica, jasper, &c. half an inch in diameter. The cement, however, is still argillaceous. These conglomerates, especially in the upper part of the series, are interstratified with the slates which have been called graywacke slate and clay slate. In the north of England, where this system of strata is developed on an enormous scale, and forms the splendid scenery of that country, these slates are so divided by joints and cleavage, that the planes of deposition, or stratification and lamination, are very obscure. The lowest part of the system is composed chiefly of clay slate, which sometimes contains chiastolite and hornblende. In these lowest slates no organic remains have been found, and only about 30 species in the limestone interstratified with the higher members of the series. These are perfectly developed zoophytes and molluscs; but no plants have been found. These are the lowest rocks containing organic remains. *Sedgwick in Geological Transactions, Vol 8. Phillip's Treatise on Geology, Vol. 1. p. 124. Lyell's Elements, p. 464. Also Principles of Geology, Vol. 2. p. 452.*

### 5. Primary rocks.

*Rem.* As the non-fossiliferous or primary rocks have no settled order of superposition, different writers will describe them in different order. I shall give them in the order in which they most usually occur, especially in this country.

1. *Clay Slate or Argillaceous Slate.* This rock is composed of fine argillaceous matter which has a fissile structure, and in the most perfect varieties its surface is more or less shining from chloritic or plumbaginous matter. Its principal deposit has already been described, as a part of the Cambrian System. But it occurs frequently interstratified with mica slate and quartz rock: and must, therefore, be regarded as a non-fossiliferous primary rock. Yet, on the other hand, it also occurs interstratified with fossiliferous Graywacke. There seems, therefore, a necessity for regarding clay slate as belonging both to the fossiliferous and non-fossiliferous strata. The farther we recede from the line separating these two classes of rocks towards the oldest, the more highly glazed does the clay slate become, until it passes at length insensibly into mica slate, talcose slate, or hornblende slate: but receding from that line in the other direction, its surface becomes more dull, and its texture looser, until it forms what is usually termed *shale*: and if we follow it still higher up in the series, it becomes gradually changed into unconsolidated clay.

2. *Quartz Rock.* This rock is essentially composed of quartz, either granular or arenaceous. The varieties result from the intermixture of mica, feldspar, talc, hornblende, or clay slate. In these compound varieties the stratification is remarkably regular: but in pure granular quartz it is often difficult to discover the planes of stratification. It is interstratified with every one of the primary rocks, and also with graywacke; in which last case it often assumes a decidedly mechanical structure: and even when a member of the primary series, this structure is sometimes visible. *Macculloch's Principles of Geology, Vol. 2. p.* 174. *Also Geological Classification, p.* 317.

3. *Hornblende Slate.* Hornblende predominates in this rock: but its varieties contain feldspar, quartz, and mica. When it is pure hornblende, its stratification is often indistinct, and it passes, by taking feldspar into its composition, into a rock resembling greenstone. It occurs in every part of the primary series; but its more common associations are argillaceous slate, mica slate and gneiss; into which it passes by insensible gradations.

4. *Talcose Slate.* The talc in this rock, which is the essential ingredient, and is sometimes in a pure state, is usually mixed with quartz and mica, and sometimes with limestone, feldspar, and hornblende. It is associated sometimes with argillaceous slate, and even graywacke: but usually, at least in the United States, with mica slate, and rarely with gneiss.

5. *Serpentine.* This is usually regarded as a simple mineral, which contains about 40 per cent. of magnesia; and it is in fact a hydrated silicate of magnesia. Most European writers describe it among the unstratified rocks; and no doubt it does frequently occur without any parallel division into strata, and in the form of veins. But the vast beds of it in the primitive regions of N. England are often distinctly stratified; and I therefore follow Dr. Macculloch, who places this rock both in the stratified and the unstratified class; because this arrangement corresponds best with its characters in Scotland.

6. *Primary Limestone.* Limestone that alternates with primary strata is called *primary.* Dr. Macculloch considers such alternation the only decided proof that limestone is primary. (*Principles of Geology, Vol.* 2. *p.* 209.) Others, as De la Beche, make its primary character to depend more upon its crystaline character; and hence assert that it occurs interstratified with fossiliferous rocks. (*Manual of Geology p.* 435.) It is generally white and crystaline, resembling loaf sugar so much as to be called *saccharine.* But in some situations it is dark colored, by being penetrated with other rocks, and also nearly compact.

7. *Mica Slate.* This is a slaty mixture of mica and quartz, in which the former predominates. Garnet and Staurotide are often so abundant in it, over extensive tracts, as properly to be regarded as constituents: hence the varieties, *Garnetiferous and Staurotidiferous* mica slate. This is one of the most common and best characterized of the primary rocks.

8. *Gneiss.* The essential ingredients in this rock are quartz, feldspar, and mica. Hornblende is occasionally present. These ingredients are arranged more or less in laminæ, and the rock is stratified. Where it passes into granite, however, (which is composed of the same ingredients), the stratification, as well as the laminar arrangement, becomes exceedingly obscure; and it is impossible to draw a definite line between the two rocks. Gneiss, as well as mica slate, is remarkable in some places for tortuosites and irregularities exhibited by their strata and laminæ: while in other places these same rocks are equally distinguished for the regularity and evenness of the stratification, by which they are rendered excellent materials for economical purposes.

*Prin.* If all the stratified rocks have been deposited from water, as we have seen, the layers must have been originally nearly horizontal.

*Inference.* Hence if we get the perpendicular thickness of a series of strata we ascertain the character of the crust of the globe to that depth.

*Facts.* By measurements and calculations of this sort, it has been ascertained that the total

thickness of the fossiliferous strata in Europe, is not less than, 6 1-2 miles. (*See Tabular view in Section* 1.) In Pennsylvania, the fossiliferous rocks beneath the top of the coal measures, are 40,000 feet, or more than 7 1-2 miles in thickness, (*Prof. Roger's Report on the Geology of Pennsylvania for* 1838, *p.* 82.

*Fact.* Dr. Buckland estimates the total thickness of all the stratified rocks in Europe to be at least ten miles. *Bridgewater Treatise, Vol.* 1. *p.* 37.

*Inference.* We see from these statements how groundless is the opinion, that geologists are able to ascertain the structure of the earth only to the depth that excavations have been made, which is less than a mile; especially when we recollect, that the unstratified rocks are uniformly found beneath the stratified; and since their igneous origin is now generally admitted, it can hardly be doubted that they come from very great depths: so that probably the essential composition of the globe is known almost to its center.

## SECTION IV.—LITHOLOGICAL CHARACTERS AND RELATIVE AGE OF THE UNSTRATIFIED ROCKS.

*Prin.* The differences among the unstratified rocks result from two causes: 1. a difference in chemical composition: 2. the diversity of circumstances under which they were produced.

*Descrip.* The two predominant and characteristic minerals in the unstratified rocks, are feldspar and augite, or hornblende, which are essentially the same in composition.

*Def.* The melted matter that is ejected from a volcano, or remains within it, is called *lava.* Hence it is not improper to apply the term to any rock that is proved to have been in a melted state. But it is usual to confine it to the more modern unstratified rocks, such as have been ejected from a crater.

*Rem.* The igneous origin of all the unstratified rocks is now so generally admitted, that we may take it for granted; and make it the basis of classification—The proof, however, will be presented in a subsequent Section.

*Descrip.* Lava cooled rapidly, and not under pressure, forms glass, or scoria: but cooled slowly, and under pressure, it becomes crystaline. Now the older unstratified rocks, such as granite, sienite, porphyry, and greenstone, are more or less crystaline: whereas basalt, trachyte, and other products of existing volcanos, are compact or cellular. Nor have we any but presumptive proof, that the former class is now produced by igneous action. Hence it is inferred, that they were cooled under a vast pressure of the ocean and its subjacent beds: and hence they are called *Plutonic Rocks:* whereas the latter are denominated *Volcanic Rocks. Phillip's Treatise on Geology Vol.* 2. *p.* 52. *Lyell's Elements of Geology, p.* 14.

### 1. *Granite.*

*Descrip.* The essential ingredients of this rock are quartz, feldspar, and mica. Its prevailing colors are white and flesh-colored. In some cases the materials are very coarse, the crystaline fragments being a foot or more in diameter: in other cases, they are so fine as to be scarcely visible to the naked eye: and between these extremes, there exists an almost infinite variety. The fine grained varieties are best for economical uses; but the coarser varieties abound most in interesting simple minerals.

### 2. *Sienite.*

*Def.* Sienite is composed essentially of feldspar, quartz, and hornblende, the first predomina-

ting. When mica is also present, the compound is frequently denominated *Sienitic Granite. Traite Elementaire de Geologie, Par M. Rozet, Tome* 1. *p.* 482.

### 3. *Porphyry.*

*Def.* Rocks with a homogeneous, compact, or earthy base, through which are disseminated crystaline masses of some other mineral of contemporaneous origin with the base, are denominated *porphyry.* True classical porphyry, such as was most commonly employed by the ancients, has a base of compact feldspar, with imbedded crystals of feldspar. When the base is greenstone, pitchstone, trachyte, or basalt, the porphyry, is said to be greenstone porphyry, pitchstone porphyry, trachytic porphyry, and basaltic porphyry. The base is sometimes clinkstone, or claystone, and the imbedded crystals may be feldspar, augite, olivine, &c.

### 4. *Greenstone.*

*Descrip.* Several unstratified rocks, whose principal ingredients are feldspar and hornblende or augite, are called *Trap Rocks:* from the Sweedish word *Trappa,* a stair: because they are often arranged in the form of stairs or steps. Although the term trap is loosely applied, most writers limit it to the varieties of rock called greenstone, sienitic greenstone, basalt, compact feldspar, clinkstone, pitchstone, wacke, amygdaloid, augite rock, hypersthene rock, trap-porphyry, pitchstone porphyry, and tufa. Macculloch includes claystone and sienite. *System of Geology, Vol.* 2. *p.* 80.

*Descrip.* Greenstone is ordinarily composed of hornblende and feldspar, both compact and common, the former in the greatest quantity.

### 5. *Trachyte.*

*Descrip.* Trachyte is of a whitish or grayish color, usually porphyritic by feldspar crystals, and essentially composed of glassy feldspar, with some hornblende, mica, titaniferous iron, and sometimes augite. *Beudant's Traite de Mineralogie, Tome* 1. *p.* 566. *Lyell's Elements of Geology, p.* 154. Its name is derived from the Greek, τραχυς, *rough,* from its harshness to the touch. It was an abundant product of volcanic action during the tertiary period, and usually appears to be older than basalt, although trachytic lavas have continued to be ejected down to the present day. Trachyte occurs in Auvergne and Hungary, and in vast quantities in South America: but not in the United States. It constitutes the loftiest summits of the Cordilleras. *Humboldt's Geognostical Essay on the Superposition of Rocks, p.* 423.

### 6. *Basalt.*

*Descrip.* This rock appears to be composed of augite, feldspar, and titantiferous iron; and sometimes olivine in distinct grains. Its color is black, bluish, or grayish; and its texture compact and uniform—more so than greenstone. Augite is the predominant ingredient. Probably in some cases, hornblende takes the place of augite: but from the nature of these two minerals, this can be regarded as of little importance. Basalt passes insensibly into all other varieties of trap rocks. *De la Beche's Manual of Geology p.* 452. *Lyell's Elements, p.* 153.

### 7. *Amygdaloid.*

*Descrip.* This term, like porphyry, is not confined to any one sort of rock; but indicates a

certain form, which extends through all the trap family. Amygdaloid abounds in rounded cavities, like the scoriae and pumice of modern lavas, and these are often filled with calcareous spar, quartz, chalcedony, zeolites, and other minerals, which have taken the shape of the cavity: so that the rock appears as if filled with almonds, and hence the name, from the Latin *amygdala*, an almond. These cavities, however, have sometimes been lengthened by the flowing of the matter while melted, so that cylinders are formed several inches long. When they are not filled, the rock is said to be vesicular.

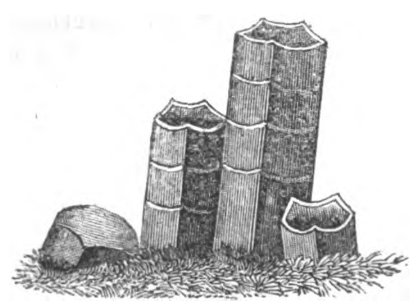
*Descrip.* A soft variety of trap rock resembling indurated clay, is called *wacke*, which may or may not be vesicular. From its resemblance to the toad, in aspect, probably, it is called in Derbyshire, *Toadstone*.

## *Prismatic or Columnar Structure.*

*Descrip.* One of the most remarkable characteristics of the trap rocks, is their columnar structure. This consists in the occasional division of their substance into regular prisms, with sides varying in number from three to eight, usually five or six, whose length is sometimes not less than 200 feet. They are sometimes jointed; that is, divided crosswise into blocks, from one to several feet in length: whose extremities are more or less convex or concave, the one fitting into the other. Frequently these columns stand nearly perpendicular, and when worn away on the side, they present naked walls which appear like the work of art. They stand so closely compacted together, that though perfectly separable, there is no perceptible space between them. The thickness of the columns varies from one to five feet.

*Remark.* 1. The concave extremity is usually uppermost. But at Titan's Pier at the foot of Mount Holyoke, in Hadley, some of the columns are convex at the top. The following sketch, Fig. 217, shows their appearance at the Giant's Causeway in Ireland.

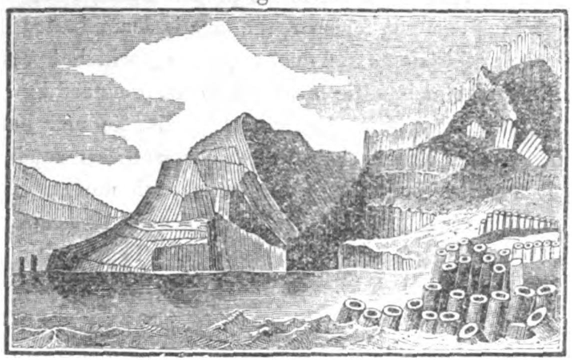
Fig. 217.



*Remark.* 2. The columnar and trappose forms of basalt and greenstone have produced some of the most remarkable scenery on the globe. Fingal's Cave in the island of Staffa, (one of the Western Islands of Scotland,) and the Giant's Causeway in the north of Ireland, are almost too well known to need description. Staffa is composed entirely of basalt with a thin soil, and its shores are for the most part a steep cliff, 70 feet high, formed of columns. The cave is a chasm, 42 feet wide, and 227 feet long, among these columns, formed by the action of the waves. The following sketch, Fig. 218, will convey an idea of the situation of the cave and of the general structure of the Island.

*Remark.* 3. Greenstone columns standing upright, or leaning only a few degrees, are quite common in North America; and form some of our most interesting scenery. The most extensive formation of this sort appears to be in the country west of the Rocky Mountains, where the

Fig. 218.



*Fingal's Cave: Staffa.*

Columbia river passes through mountains of trap, (not improbably of basalt,) from 400 to 1000 feet high; and where several successive rows of columns are superimposed upon one another, separated by a few feet of amygdaloid, conglomerate, or breccia. *Parker's Journal of an Exploring Tour beyond the Rocky Mountains, p.* 208. *Ithaca,* 1838.

The Palisadoes on the banks of Hudson river are another example of greenstone columns. They exist also, on Penobscot river; and very perfect examples occur on Mount Holyoke and Tom, on Connecticut river, as has been shown in the third part of this Report.

*Prin.* The columnar structure of the trap rocks, has resulted from a sort of crystalization while they were cooling under pressure from a melted state.

*Proof.* 1. Precisely similar columns are found in recent lavas, (*Wonders of Geology, Vol.* 1, *p.* 248, 250, *and Vol.* 2. *p.* 640.) 2. Mr. Gregory Watt melted 700 pounds of basalt and caused it to cool slowly; when globular masses were formed, which enlarged and pressed against one another until regular columns were the result. *Bakewell's Geology, p.* 146.

## 8. *Serpentine.*

*Descrip.* This rock has been already described in the section on the stratified rocks, and the reasons stated for placing it among the stratified as well as unstratified rocks.

## 9. *Lava.*

*Descrip.* Lava, as remarked in another place, embraces all the melted matter ejected from volcanos: and the two minerals feldspar and augite, constitute almost the entire mass of these products. When the former predominates, light colored lavas are the result: when the latter the dark varieties. The former are called *feldspathic* or *trachytic*, and the latter, *augitic* or *basaltic* lavas.

*Descrip. Trachytic Lava* corresponds in most of its characters to the trachyte of the older igneous rocks. When cooled under pressure, solid rock results; but when cooled in the air, it is porous, fibrous, and light enough to swim on water, as is the case with pumice, large masses of which are found sometimes in the midst of the ocean. Sometimes it is porphyritic, like the older trachytes.

*Descrip.* In like manner the basaltic or augitic lavas exceedingly resemble the more ancient basalt; and are in fact the same thing, produced under circumstances a little different. When cooled under pressure, compact basalt is the result; but cooled in the open air, they become scoriaceous or vesicular, and are usually called Scoriæ.

*Descrip. Graystone Lava*, is a lead gray or greenish rock, intermediate in composition be-

tween basaltic and trachytic lavas: but the feldspar predominates, being more than 75 per cent. When albite takes the place of common feldspar, the lava is denominated *Andesitic*.

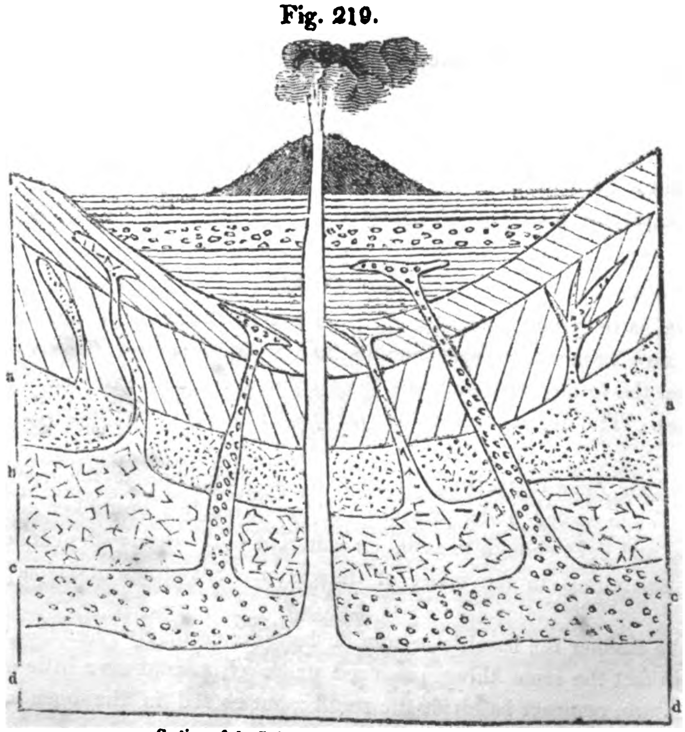
*Descrip.* The small angular fragments and dust of pumice, (which is vesicular trachytic lava,) and of scoriæ, (which are vesicular basaltic lava) which are produced by an eruption falling into the sea, or on dry land, and mixing with sand, gravel, shells, &c. and hardened by the infiltration of carbonate of lime or other cement, constitute the substance denominated *Tuff.* When this rock occurs with trap, it is called *Trap Tuff*; and when with modern lava, *Volcanic Tuff.* If it contain large and angular fragments, it is called *Volcanic Breccia.* When the fragments are much rolled, the rock is a *Tufaceous Conglomerate.* The basaltic tuffs are denominated by the Italian geologists, *Peperino:* A kind of mud is poured out of some volcanic craters which forms what is called *Trass.*

## *Relative Age of Rocks.*

*Prin.* In the stratified rocks the relative age of the different groups is determined by their superposition; the lowest being the oldest: but in the unstratified rocks, there is reason to believe a reverse order exists: that is, the oldest member of the series lies immediately beneath the stratified rocks; the next oldest beneath this; and so on, till we reach the lava of existing volcanos; which probably comes from a greater depth in the earth than any other unstratified rocks.

*Illustration.* Fig. 219, will more clearly illustrate this proposition.

Fig. 219.




*Section of the Relative Age of the Unstratified Rocks.*

*Prin.* The ages of the unstratified compared with those of the stratified rocks, are determined by ascertaining how far the former have intruded upward among the latter.

*Illustration.* If for instance, we never find the veins of a particular igneous rock shooting upward higher than the primary rocks, we may infer that it is older than the secondary strata, but newer than the primary: because the latter must have existed prior to the intrusion of the unstratified rock. And so, if an igneous rock is intruded only into the primary and secondary strata, we may infer that it is older than the tertiary strata, and newer than the secondary: and so on with the groups still higher. Hence the igneous rocks a, a, Fig. 219, formed during the deposition of the primary strata, whose veins extend no higher than those strata, may be called, (to adopt the phraseology of Mr. Lyell,) the *Primary Plutonic:* those during the deposition of the secondary strata, b, b, whose veins do not enter the tertiary series, the *Secondary Plutonic:* those during the deposition of the tertiary strata, c, c, the *Tertiary Plutonic:* and lava from active volcanos, d, d, the *Recent Plutonic.*

*Descrip.* In reality, however, we do not find varieties of unstratified rocks whose veins are thus distinctly confined to each of the great classes of rocks, though there is evidence that volcanic agency was active during all the periods of their deposition. But the same igneous rock appears to have been ejected at different epochs. Granite, however, seems to have greatly predominated during the first or primary period; and is found only occasionally during the secondary period; though in a few instances (at Weinbohla) sienitic granite has been protruded through the chalk, but never among the tertiary strata. Porphyry appears to have been mostly confined to the period of the latest primary, and the older secondary (transition) rocks. Trap rock predominated in the secondary and tertiary periods, while volcanic rocks, in the common acceptation of the term, began to be protruded during the tertiary period, and continue to the present time.

*Inf.* From the phenomena that have been detailed respecting the unstratified rocks, it has been inferred that the condition of the earth, both internal and external, must have been different at different epochs; so as at one period to be peculiarly favorable for the production of granite and sienite, at another of porphyry, at another of trachyte, at another of basalt, and finally at another of the lava of extinct and active volcanos; and hence, that the older igneous rocks, (ex. gr. granite, sienite, &c.) are no longer produced, except perhaps in the deep recesses of the earth.

## Section V.—Palæontology, or the Science of Organic Remains.

*Def.* In all the stratified rocks above the primary, more or less of the relics or traces of animals and plants occur, sometimes called petrifactions, but more commonly, *Organic Remains.*

*Def.* That branch of Geology, which gives the history of these remains, was formerly denominated *Oryctology:* but is now called *Palæontology.*

### 1. *General Characters of Organic Remains.*

*Descrip.* In a few instances, animals have been preserved entire in the more recent rocks.

*Example.* About the beginning of the present century the entire carcass of an elephant was found encased in frozen mud and sand in Siberia. It was covered with hair and fur, as some elephants now are in the Himalayah mountains. The diluvium along the shores of the Northern Ocean, abounds with bones of the same kind of animals: but the flesh is rarely preserved. *Cuvier's Essay on the Theory of the Earth, p.* 253, *New York,* 1818. *De la Beche's Manual of Geology, p.* 200. In 1771, the entire carcass of a rhinoceros was dug out of the frozen gravel of the same country. *Bakewell's Geology, p.* 331.

*Descrip.* Frequently the harder parts of the animal are preserved in the soil or solid rock scarcely altered.

*Descrip.* Sometimes the harder parts of the animal are partially impregnated with mineral matter; yet the animal matter is still obvious to inspection.

*Descrip.* More frequently, especially in the older secondary rocks, the animal or vegetable matter appears to be almost entirely replaced by mineral matter, so as to form a genuine *petrifaction*.

*Descrip.* Sometimes after the rock had become hardened, the animal or plant decayed and escaped through the pores of the stone, so as to leave nothing but a perfect *mould*.

*Descrip.* After this mould had been formed, foreign matter has been infiltrated into it through the pores of the rock, so as to form a *cast* of the animal or plant when the rock is broken open. Or the cast might have been formed before the decay of the animal or plant.

*Descrip.* Frequently the animal or plant, especially the latter, is so flattened down that a mere film of mineral matter alone remains to mark out its form.

*Descrip.* All that remains of an animal sometimes is its track impressed upon the rock.

*Descrip.* The mineralizer is most frequently carbonate of lime: frequently silica, or clay, or oxide or sulphuret of iron, and sometimes the ores of copper, lead, &c.

## 2. *Nature and Process of Petrifaction.*

*Def.* Petrifaction consists in the substitution, more or less complete, by chemical means, of mineral for animal or vegetable matter. *De la Beche's Theoretical Geology, Chap.* 13.

*Descrip.* The process of petrifaction goes on at the present day to some extent, whenever an animal or vegetable substance is buried for a long time in a deposit containing a soluble mineral substance that may become a mineralizer.

## 3. *Means of determining the Nature of Organic Remains.*

*Prin.* The first requisite for determining the character of organic remains, is an accurate and extensive knowledge of zoology and botany. This will enable the observer to ascertain whether the species found in the rocks are identical with those now living on the globe.

*Prin.* The second important requisite is a knowledge of Comparative Anatomy: a science which compares the anatomy of different animals and the parts of the same animals.

*Remark.* This recent science reveals to us the astonishing fact, that so mathematically exact is the proportion between the different parts of an animal, "that from the character of a single limb, and even of a single tooth, or bone, the form and proportion of the other bones, and the condition of the entire animal may be inferred."—"Hence, not only the frame work of the fossil skeleton of an extinct animal, but also the character of the muscles, by which each bone was moved, the external form and figure of the body, the food, and habits and haunts, and mode of life of creatures that ceased to exist before the creation of the human race, can with a high degree of probability be ascertained. *Buckland's Bridgewater Treatise, Vol. I. p.* 109. See also *Cuvier's Ossemens Fossiles, Tome I. p.* 47. *Troisieme Edition.*

## 4. *Classification of Organic Remains.*

*Prin.* Organic remains may be divided, according to their origin, into three classes: 1. Marine. 2. Freshwater. 3 Terrestrial.

*Remark.* The following table will show the origin of the remains in the different groups of fossiliferous rocks.

| | |
|---|---|
| Cambrian and Silurian Systems, (Graywacke,) | Marine. Rarely Terrestrial. |
| Old Red Sandstone, | Marine. |
| Carboniferous Limestone, | Do. |

| | |
|---|---|
| Coal Measures. Terrestrial Estuary Deposits and submerged land. Rarely perhaps fresh water deposits. | |
| New Red Sandstone Group, | Marine. |
| Oolitic Group, but in a few instances, | Mostly Marine. Terrestrial. |
| Wealden Rocks, | Estuary Deposit. |
| Cretaceous Group, | Marine. |
| Tertiary Strata, | Marine and Fresh Water. |
| Diluvium, | Terrestrial. |

*Inference.* It appears from the preceding statements, that by far the greatest part of organic remains are of marine origin. Nearly all the terrestrial relics, indeed, and many of fresh water origin, have been deposited beneath the waters of the ocean.

### 5. *Amount of Organic Remains in the Earth's Crust.*

*Descrip.* The thickness of the fossiliferous strata in Great Britian, as has already been given in former Sections, so far as ascertained, is as follows.

| | |
|---|---|
| Tertiary Strata, | 1350 feet. |
| Chalk, | 600 " |
| Green Sand, | 480 " |
| Wealden Group, | 900 " |
| Oolite—mean thickness, | 1230 " |
| Lias, | 1050 " |
| New Red Sandstone, | 900 " |
| Magnesian Limestone, | 300 " |
| Coal Measures, | 3000 " |
| Millstone Grit, | 900 " |
| Carboniferous Limestone, | 1800 " |
| Old Red Sandstone, | 5100 " |
| Silurian Rocks, | 7470 " |
| Cambrian Rocks at least, | 9000 " |

Total, 34080 feet, or about 6 1-2 miles. *Phillips' Geology, p.* 34 *and* 80.

*Descrip.* Organic remains occur more or less in all the fossiliferous strata whose thickness has been given. As a matter of fact, they have been dug out several thousands of feet below the surface.

*Descrip.* In the Alps, rocks abound in organic remains from 6000 to 8000 feet above the level of the sea: in the Pyrenees, nearly as high; and in the Andes, at the height of 14000 feet.

*Descrip.* Frequently beds or layers of rocks, many feet in thickness, appear to be made up almost entirely of the remains of animals or plants: indeed, whole monutains, hundreds and even thousands of feet high, are esentially composed of organic matter.

*Descrip.* Prodigious accumulations of the relics of microscopic animals are frequently found in the rocks.

*Examples.* 1. From less than 1 1-2 ounce of stone, in Tuscany, Soldani obtained 10.454 chambered shells, like the Nautilus :—400 or 500 of these weighed only a single grain; and of one species it took 1000 to make that weight. These were marine shells. *Buckland's Bridgewater Treatise, Vol.* 1. *p.* 117.

*Ex.* 2. But perhaps the most remarkable example is that derived from the recent disoveries of the Prussian naturalist, Ehrenberg, respecting the fossil remains of animalculæ. In one place in Germany is a bed 14 feet thick, made up of the shields of animalculæ so small that it requires

41.000.000.000 of them to form a cubic inch: and in another place, a similar bed is 28 feet thick.

*Descrip.* It is a moderate estimate to say, that two thirds of the surface of our existing continents are composed of fossiliferous rocks; and these as already stated, often several thousand feet thick.

### 6. *Distribution of Organic Remains.*

*Descrip.* Existing animals and plants are arranged into distinct groups, each group occupying a certain district of land or water; and few of the species ever wander into other districts. These districts are called Zoological and Botanical Provinces: and very few of the species of animals and plants which they contain, can long survive a removal out of the province where they were originally placed; because their natures cannot long endure the difference of climate, food, and other changes to which they must be subject.

*Descrip.* In some instances, organic remains are broken and ground by attrition into small fragments, like those which are now accumulating upon some beaches by the action of the waves: But often the most delicate of the harder parts of the animal or plant are preserved; and they are found to be grouped together in the strata very much as living species now are on the earth.

*Inference.* From these facts it is inferred, that for the most part, the imbedded animals and plants lived and died on or near the spot where they are found; while it was only now and then that there was current enough to drift them any considerable distance, or break them into fragments. As they died, they sunk to the bottom of the waters and became enveloped in mud, and then the processes of consolidation and petrifaction went slowly on, until completed.

*Remark.* Were the bottom of our existing oceans and lakes, where mud, sand and gravel have been accumulating for ages, and enveloping the animals and plants that have died there, or been drifted thither, were this to be now elevated above the waters, we should find exactly such an arrangement of organic remains, as we find in a particular formation of the solid rocks. While there would be a resemblance between the relics in different seas and lakes, there would be great specific diversity; just as we find in different groups of rocks in different countries: and hence the conclusion seems fair, that these rocks with their contents had an origin similar to the deposits now forming at the bottom of existing bodies of water.

*Prin.* In comparing organic remains from different formations, it should be recollected that they may belong to the same class or order, or genus, and yet be widely different from one another: and that it is only when they are of the same *species*, that they are identical.

*Descrip.* If we compare together the remains of the Cretaceous formation, the red sandstone formation, the carboniferous system, and the Silurian formation, in different parts of England, we shall find that those most remote from one another in locality, differ most widely: but almost without an exception, those in each formation are specifically distinct from all those in the other formations. *Phillips' Geology, p.* 51.

*Descrip.* If we compare the fossils of the Tertiary and Secondary Classes of rocks, we shall find that they have no species common, so far as has yet been ascertained, either of animal or plant. *Lyell's Geology, Vol.* 3. *p.* 327. *First Ed.*

*Descrip.* If we examine a formation through its whole extent, we shall rarely find that any species of organic remains is universally diffused, unless the extent of the formation be quite limited. If we compare the same formation in different countries, the specific resemblance between the organic contents will diminish nearly in the inverse ratio of the distance between them. *Phillips' Treatise on Geology from Ency. Brittan. p.* 52.

*Prin.* Rocks agreeing in their fossil contents, may not have been contemporaneous in their deposition.

*Proof.* The causes that have produced changes of organic life may have operated sooner upon some parts of the globe than upon others; so that particular animals and plants may have continued to be deposited in some spots longer than in others.

*Remark.* Probably, however, such a diversity in different parts of the globe could not have continued very long, so that rocks with the same organic remains may be regarded as not differing greatly in age: and besides, as already stated, there is reason to suppose that in earlier times there was greater uniformity of climate and condition on the globe than at present.

*Inf.* From all that has been advanced, it appears that an identity of organic remains is not alone sufficient to prove a complete chronological identity of rocks widely separated from each other: but it will show an approximate identity as to the period of their deposition; and in regard to rocks in a limited district, it will show complete identity.

*Prin.* If the mineral character of two rocks agree, as well as the organic contents, their synchronism will be shown to be more probable. But on the other hand, a want of agreement in the mineral characters, ought not to be regarded as proof that they were not contemporaneous.

*Prin.* Still stronger evidence of synchronism is obtained when rocks agree in their superposition, as well as in the characters above named. This character, indeed, when it can be applied, is very conclusive: but in remote regions it is applied with great difficulty.

## *Tabular View of Organic Remains.*

*Table.* The following Tabular view of the Organic Remains in the different formations, will show how the different families of animals and plants are distributed in the rocks. It is derived from the latest authorities, within my reach. But it will be seen by the references beneath the Table, that these authorities differ widely in their dates; so that some of the numbers are far more in accordance with the present state of the science than others. Nevertheless, some important inferences may be deduced from such a table: and therefore I give it, though confessedly imperfect. I have added the numbers of living species that have been described, so far as I have been able to obtain any estimates that approximated near enough to the truth to form a basis of reasoning. Of course, all the numbers of this Table must be regarded as falling far below the actual numbers, both of living and extinct species.

| Flowering Plants. | Flowerless Plants. | Mammalia. | Birds. | Reptiles. | Fishes. | Mollusca. | Annulata | Crustacea. | Arachnides. | Insects. | Radiata or Zoophyta. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50,000 | 10,000 | 1000 | 6000 | | e 8000 | c 8000 | | | | 120,000 | 2500 | **Living Species.** |
| | | a 99 | a 20 | | | Sever-al. | | | | | | **Diluvium, Caverns, and bone Breccia.** |
| b 145 | b 21 | a 98 | i 10 | h 18 | | o 4000 | d 16 | o 25 | o 9 | o 244 | d 50 | **Tertiary Strata.** |
| b 38 | b 49 | | m 1 | d 2 d 11 | o Eight Hundred and fifty Species. | a 500 | d 30 | d 7 d 1 | | | d 235 | **Chalk.** **Wealden Rocks.** |
| a 37 | a 43 | n 2 | | m 40 | | a 771 | d 59 | a 22 | i 2 | i 25 | a 273 | **Oolite.** |
| b 10 | b 13 | | 20 Tracks. | d 9 | | a 118 d 130 | d 2 | d 1 | | | d 16 | **Red Sandstone Group.** |
| b 16 | d 310 b 226 | | | | | a 366 d 214 | d 1 | d 2 | i 1 | i 3 | d 48 | **Carboniferous Group.** |
| d 2 | d 10 | | | | | a 349 d 325 | d 5 | 60 | | | d 132 | **Silurian and Cambrian Rocks.** |

**a.** Professor John Phillip's Treatise on Geology, 1837.
**b.** Adolphe Brongniart in 1829.
**c.** Lyell's Elements and Principles of Geology, 1838.
**d.** De la Beche's Manual of Geology, Third Edition, 1833.
**e.** Agassiz.
**h.** Al. Brongniart. Tableau des Terrains, 1829.
**i.** Buckland's Bridgewater Treatise, 1836.
**m.** Mantell's Wonders of Geology, 1838.
**n.** Mining Review, Dec. 1838.
**o.** Prof. Bronn's Lethaæ Geognostica, Stuttgart, 1838.

*Inference* 1. From the preceding table we learn that all the important classes of animals and plants are represented in the different formations.

*Inference* 2. We learn, however, that in the earlier periods of the world, the less complex and perfect tribes of animals and plants greatly predominated, and that the more perfect species became more and more numerous up to the creation of the present races.

*Inf.* 3. Vegetable life must have commenced on the globe nearly as early as animal life.

*Inf.* 4. Dry land, capable of sustaining vegetation, must have existed soon after the deposition of the fossiliferous rocks commenced.

*Descrip.* The family of Coniferous Plants is found in the earliest rocks, and at each successive change in the physical condition of the globe, the numbers of its genera and species increased, until it forms among existing plants about one three hundredth part of the whole flora, or nearly 200 species. Palms also occur, though sparingly, in all the formations.

*Descrip.* The 300 species of fossil plants found in and beneath the carboniferous strata, are two thirds tree ferns and gigantic Equisetaceæ. Ten Coniferæ, and plants intermediate between these and Lycopodiaceæ, Lepidodendriæ, Sigillariæ, and Stigmariæ, together with 10 Monocotyledonous plants, form the remainder. *Mantell's Wonders of Geology, Vol.* 2. *p.* 568.

*Descrip.* Of the 100 species found between the carboniferous strata and the tertiary groups, one third are ferns; and most of the remainder are Cycadeæ, Coniferæ, and Liliaceæ. More of the first named family have already been found fossil, than exist at present on the globe. They form more than one third of the entire fossil flora of the secondary formations; but less than the 2000th part of the existing flora.

*Descrip.* The plants of the tertiary strata approximate closely to the existing flora.

*Descrip.* Below the New Red Sandstone vascular cryptogamiæ, or flowerless plants, greatly predominate, while dicotyledonous plants are rare. In the secondary strata above the coal, there is an approach to equality between these two classes. In the tertiary strata the latter predominate; and in the existing flora, two thirds are of this class. *Buckland's Bridgewater Treatise, Vol.* 1. *p* 520.

## 7. *Periods in which different plants and animals began to appear on the Globe, and in which some of them became extinct.*

*Prin.* In general plants and animals began to exist first on the globe during the period when the lowest rock in which their remains are found was deposited.

*Proof.* 1. Those animals and plants are excepted that are too frail to be preserved in the rocks: but in respect to all others, no reason can be assigned why their remains should not be found along with those of other organic beings existing at the same period.

2. Comparative anatomy here comes in to our aid. For it is found that certain types of organic existence characterize particular geological periods: and having ascertained the type for any particular period, we may infer with great certainty that an animal or plant of a very different type will not be found among the organic remains of that formation. Thus, we find in general the fossils of the carboniferous group to have been adapted to a climate of a tropical character: and to expect to find in that group, animals or plants adapted to a temperate climate, would be unreasonable; because the two tribes could not have existed in the same climate.

*Descrip.* The following is the order in which some of the most important animals and plants have first appeared on the globe: in other words, the epoch of their creation. It may indeed, be hereafter found, when the rocks have been more extensively examined, that some appeared earlier.

| | |
|---|---|
| Silurian and Cambrian or Graywacke Period. | Zoophytes.<br>Marine Shells.<br>Crustacea (Tribolites.)<br>Placoidians and Ganoidians.<br>*Fishes*—(Sauroids and Sharks with heterocercal tails.)<br>Flowerless Plants. } Marine.<br>Flowering Plants. } Terrestrial. |
| Carboniferous Period. | *Fish:* (Cephalaspis, &c.)<br>*Arachnidans:* Scorpions.<br>*Coleopterous Insects.*<br>*Fresh Water Shells.*<br>*Dicotyledonous Plants*—Coniferæ; (Pines, &c.) Cycadeæ.<br>*Monocotyledonous Plants*, Palmae, Scitaminæ. |
| Red Sandstone Period. | Tracks of Birds, Tortoises, and Chirothria allied to Marsupialia.<br>*Reptiles:* Monitor, Phytosaurus, Ichthyosaurus, Plesiosaurus, Mastodonsaurus, Thecodontosaurus, Palæosaurus.<br>*Crustacea:* Palinurus.<br>*Fishes:* Palæoniscus, &c.<br>*Dicotyledonous Plants*, (Voltzia.) |
| Oolitic Period. | *Mammalia:* Thylacotherium.<br>*Cetacea:* Phascolotherium, (Didelphys of Buckland.)<br>*Reptiles:* Saurocephalus, Saurodon, Teleosaurus, Streptospondylus, Megalosaurus, Lacerta neptunia, Ælodon, Rhacheosaurus, Pleurosaurus, Geosaurus, Macrospondylus, Pterodactylus, Crocodile, Gavial, Tortoise.<br>*Fishes:* Pcynodontes and Lepidoides. (Dapedium, &c.) with homocercal tails.<br>*Arachnidans:* Spiders.<br>*Insects:* Libellulæ, Coleoptera.<br>*Crustacea:* Pagurus, Eryon, Sycllarus, Palæmon, Astacus.<br>*Plants:* Cycadeæ, (Pterophyllum, Zamia,) Coniferæ (Thuytes, Taxites,) Lilia, (Bucklandia.) |
| Wealden Period. | *Birds:* Grallæ, (Tilgate Forest.)<br>*Reptiles:* Iguanodon, Leptorynchus, Trionyx, Emys, Chelonia.<br>*Fishes:* Lepidotus, Pycnodus, &c. Fresh water and Estuary shells. |
| Cretaceous Period. | *Reptiles:* Mososaurus, &c.<br>*Fishes:* Ctenoidians and Cycloidians.<br>*Crustacea:* Arcania, Etyæa, Coryster.<br>*Plants:* Confervæ, Naiades. |

| | |
|---|---|
| Tertiary Period. | *Mammalia*, 1. *Eocene Period*, 50 *species*:— Palæotherium, Anoplotherium, Lophiodon, Anthracotherium, Cheroptamus (allied to the hog), Adapis (Resembling the hedgehog) *Carnivora:* Bat, Canis (Wolf and Fox) Coatis, Racoon, Genette, Dormouse, Squirrel. *Reptiles:* Serpents.<br>*Birds:* Buzzard, Owl, Quail, Woodcock, Sea Lark, Curlew, Pelican. *Reptiles:* Fresh Water Tortoises. *Fishes:* seven extinct species of extinct genera.<br>2. *Miocene Period:* Ape, Dinotherium, Tapir, Chalicotherium, Rhinoceros, Tetracaulodon, Hippotherium, Sus, Felis, Machairodus, Gulo, Agnotherium, Mastodon. Hippopotamus, Horse.<br>3. *Pliocene Period:* Elephant, Ox, Deer, Dolphin, Seal, Walrus, Lamantin, Megalonyx, Megatherium, Hyaena, Ursus, Weasel, Hare, Rabbit, Water Rat, Mouse, Dasyurus, Halmaturus, Kangaroo and Kangaroo Rat.<br>*Birds:* Pigeon, Raven, Lark, Duck, &c.<br>*Fishes:* (in the formation generally) more than 100 species now extinct, which belong to more than 40 extinct and as many living genera.<br>*Insects:* 162 genera of Diptera, Hemiptera, Coleoptera, Aptera, Hymenoptera, Neuroptera, and Orthoptera*.<br>*Shells:* In the Newer Pliocene Period, 90 to 95 per cent. of living species; 35 to 50 per cent. in the older Pliocene: 17 per cent. in the Miocene: and 3 1-2 per cent. in the Eocene; amounting in all to 4000 species.<br>*Plants:* Poplars, Willows, Elms, Chesnuts, Sycamores, and nearly 200 other species: seven-eighths of which are monocotyledonous or dicotyledonous. |
| Alluvial Period. | Man and most of the other species of existing animals and plants. |

## *Human Remains.*

*Prin.* Geology alone has as yet been unable to fix the precise time when man first appeared on the globe; but it was certainly very recent, and one of the last displays of creative energy witnessed on the earth.

*Inference.* Until the exact period can be fixed when the remains of man first appear in the strata, geological time cannot be connected with historical time very definitely.

*Proof.* The scriptures fix the chronology of man's creation; so that if we can determine during what geological period this took place, we can ascertain what changes have occurred since; and what events preceded his appearance. To fix the date of any other existing animal's creation, will not in like manner connect geological and historical dates, because some of the existing species are mixed with extinct races, and may have been recreated during the six demiurgic days of the scripture.

* Bronn's Lethea Geognostica, p. 811.

## 8. *Vertical Range of Animals and Plants in the Strata.*

*Descrip.* Not only did different species, genera, and families of animals commence their existence at very different epochs in the earth's history, but some of them soon became extinct; others continued longer, and some even to the present time.

*Descrip.* Species rarely extend from one formation into another; but genera frequently continue through several formations; and a few, even through the whole series of strata: and are still found among living animals and plants. Orders are still more extensive in their vertical range; and all the great classes, as has been shown, extend through the whole series. Very many genera, however, and some orders, are limited to a single formation. Others, after disappearing through one or more formations, again reappear.

Out of the multitudes of Cephalopods, or chambered shells, that swarmed in the ancient seas, only two species have continued to the present time; as may be seen by the following Table of their vertical range.

| | Bellerophon. | Orthocera. | Belemnites. | Nautilus. | Ammonites. | Hamites. | Scaphites. | Baculites. | Nummulites. |
|---|---|---|---|---|---|---|---|---|---|
| Living Species. | | | | 2 | | | | | |
| In Tertiary Strata. | | | | 4 | | | | | |
| In Cretaceous System. | | | 8 | 9 | 57 | 28 | 4 | 5 | 3 |
| In Oolitic do. | | | 75 | 13 | 164 | 2 | 1 | | |
| In Saliferous do. | | | | 2 | 3 | | | | |
| In Carboniferous do. | 13 | 28 | | 26 | 33 | | | | |
| In Graywacke do. | 11 | 29 | | 3 | 17 | | | | |

## 9. *Comparison of Fossil and Living Species.*

*Prin.* It is a moderate estimate to reckon the species of organic remains hitherto described in the rocks below the tertiary strata, at 5000. Yet scarcely none of this number have thus far been identified with any now living on the globe. In many cases they differ even generically.

*Rem.* The above estimate would make the whole number of fossil species 9000.

***Prin.* The deeper we descend into the earth, that is, the older the rock, the more unlike in general are its orgainc remains to existing species. As we ascend, we find a nearer and nearer approximation to existing species in each successive formation.**

*Descrip.* In 1833 the number of shells in the tertiary strata that had been discovered and described by M. Deshayes in Europe, amounted to 3036: Of these, 568 were identical with spe-

cies found in our present seas. They were distributed however, very unequally through the different groups of these strata as follows.

| | | | |
|---|---|---|---|
| In the Eocene or oldest Group, | 1238 species: | Living analogues, | 42. |
| In the Miocene, | 1021 do. | do. | 176. |
| In the Pliocene, | 777 do. | do. | 350. |

***Prin.*** **The organic remains in the northern parts of the globe, correspond more nearly to existing tropical plants and animals, than those now living in the same latitudes.**

*Proof.* It is well known that the Fauna and Flora of tropical regions are so different from those in higher latitudes as to strike every observer. Now any one who is acquainted with these peculiar features of tropical organic life, even as they are exhibited in books, will be struck with their resemblance to the organic remains in the fossiliferous strata. The following examples may serve for illustration: beginning with the highest of the strata, viz. diluvium. 1. Along the shores of the Arctic Ocean in the banks of the great rivers, such as the Oby, the Yenesi, and the Lena, are found immense quantities of the bones of the extinct species of elephant called the mammoth. The region in which these remains occur, is almost as large as the whole of Europe. Now although the fact that these animals were covered with hair, proves that the climate where they lived, was colder than that where naked elephants now live, yet it must have been much warmer than the present temperature of Siberia, in order to produce vegetables for their sustenance. The rhinoceros found fossil in the same country confirms this conclusion. 2. The bones of extinct species of elephant, rhinoceros, hippopotamus, lion, tiger, hyæna, &c. genera confined almost exclusiyely within the tropics at this day, are found scattered through the diluvium of almost every part of Europe. 3. When shells are found in the tertiary strata in northern countries, identical with those in existing seas, their analogues are almost universally found in tropical seas: and when the same species occurs in the Mediterranean, for instance, as is found fossil upon its shores, the latter is much larger than the former: and it is a well known fact that the same species in tropical regions attain a greater size than in colder climates. 4. The great size, both of the animals and plants found in the secondary strata, compared with that of living organic beings of a similar kind, shows a state of climate during their growth very favorable to their developement: such a climate, in fact, as exists in tropical countries. 5. The great number of chambered shells, such as ammonite, orthocera, &c. found in the secondary rocks, confirms this proposition, since the few representatives of these shells still found alive, occur in warm latitudes. 6. But perhaps the most striking evidence of a warm climate, during the deposition of the secondary rocks, exists in the fossil flora of the coal formation. This is filled with gigantic plants of genera mostly found within the tropics; such as equiseta, lycopodiaceæ, tree ferns, palms, &c.: and a person who is familiar with these remains, is struck, on going to a tropical country, with their resemblance to the vegetation around him; as he is with their want of resemblance to the flora of high latitudes. These tropical plants have been found in the rocks around Baffin's Bay, and even as far north as Melville Island, in 75° north latitude. 7. Numerous organic remains in the secondary rocks, even in the oldest fossiliferous strata, appear to have once constituted coral reefs; such as are now found only in tropical seas. Such relics as these, also, have been found in the rocks of Melville Island. *Lyells' Principles of Geology, Vol.* 1. *p.* 98.

***Prin.*** It is probable that during the deposition of the older fossiliferous rocks, the climate was ultra-tropical; that is, warmer than at present exists on the globe.

***Prin.*** The temperature of the climate seems to have gradually sunk during the successive deposition of the different groups of fossiliferous rocks.

## 10. *Description of individual and peculiar Species of Organic Remains.*

### PLANTS.

*Descrip.* The number of fossil plants yet described amounts to about 600. (*Phillip's Treatise on Geology, Vol.* 1. *p.* 70.) Of these, more than 300 are contained in the strata below the top of the carboniferous Group: more than 100 in the rocks between that group and the tertiary strata; and nearly 200 in the tertiary.

### *Algæ or Sea Weeds.*

*Descrip.* Existing submarine vegetation, amounting to more than 500 species, may be arranged in three divisions; dependent for their characters upon climate: the first group occupying the frigid, the second the temperate, and the third the torrid zone. A similar distribution of the fossil marine plants, will bring all those below the top of the new red sandstone into the class of tropical plants: while those higher in the series, approximate more and more to those now existing on the globe. *Adolphe Brongniart's Histoire des Vegetaux Fossiles, Livraison* 1. *p.* 41.

*Descrip.* In the lowest rocks most of the plants are marine. Fig. 220, represents a species of fucoides.

Fig. 220.

*Fucoides.*

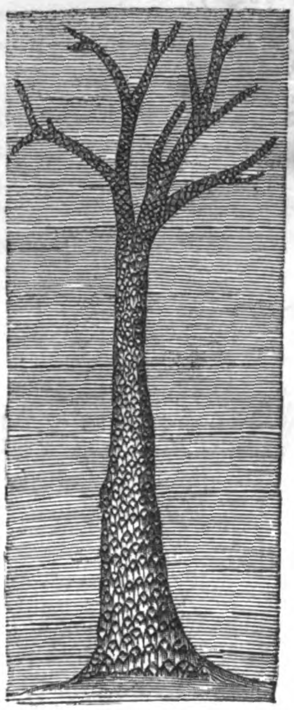
Fig. 221.

*Tree Ferns.*

### *Musci and Filices: or Mosses and Ferns.*

*Descrip.* On account of their delicate structure, mosses are rarely preserved in the rocks. But ferns are very abundant; especially in the more ancient strata, where they are found of a size at least equal to those now growing in the torrid zone, which are often from 40 to 50 feet high. Fig. 221, is asketch of some of these tree ferns, now growing in tropical climates.

Fig. 222.



*Lepidodendron.*

*De crip.* Europe at the present time does not contain more than 30 or 40 species of ferns, and these of diminutive size; whereas more than 200 species have been found in the coal formation of the same quarter of the globe. *Adolphe Brongniart in American Journal of Science, Vol.* 34. *p.* 319.

## *Lycopodiaceæ, or Club mosses.*

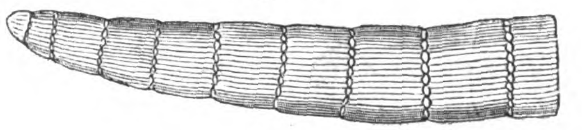
*Descrip.* The Lycopodiaceæ are a tribe of plants intermediate between ferns and coniferæ on the one hand, and ferns and mosses on the other. *Lindley's Natural System of Botany*, *p.* 313.

*Lepidodendron.* This fossil plant approximates in its character to the Lycopodiaceæ: or rather, it seems to be intermediate between the club moss tribe, and the coniferæ or pine tribe. It is abundant in the coal formation, where it is sometimes found from 20 to 45 feet long; and M. Ad. Brongniart has described 34 species. The genus is wholly extinct. Fig. 222 will convey some idea of these plants.

## *Equisetaceæ.*

*Descrip.* Living plants of this tribe are called *horse-tails*, *cat-tails*, *scouring rushes*, &c: and although of frequent occurrence in all climates (the most frequent in the temperate zones) they are of diminutive size, even in the torrid zone, compared to those found fossil. The latter are divided into two genera, *Equisetum* and *Calamites*: the former corresponding very nearly to living equiseta, but the latter differing a good deal in structure and size; being much larger than the equiseta. Fig. 223 is a Calamites destitute of leaves.

Fig. 223.



*Calamites.*

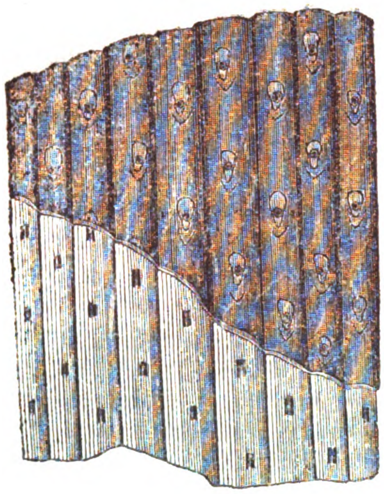
## *Plants in the Older Strata not yet referred to any living Classes with certainty.*

## *Sigillaria.*

*Descrip.* The Sigillaria are large trunks, from half a foot to three feet in diameter, and from 50 to 60 feet long, covered usually with fluting and scars. Brongniart enumerates 42 species; and regards them as closely allied to arborescent ferns: But Lindley and Hutton offer good reasons for supposing them dicotyledonous plants, different from any now on the globe, yet approaching the Euphorbiæ and Cacteæ. Fig. 224, represents the flutings and scars of one of these plants.

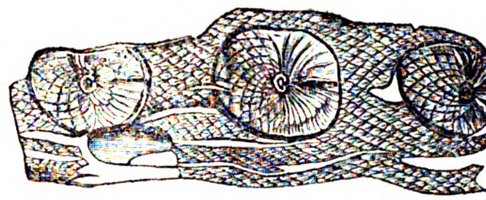
*Descrip.* Several other extinct genera, with scars similar to those on the Sigillaria; that is, arranged in vertical rows, occur in the same rocks, and are probably Coniferæ. Fig. 225, shows a portion of one called Ulodendron.

Fig. 224.



Sigillaria.

Fig. 225.

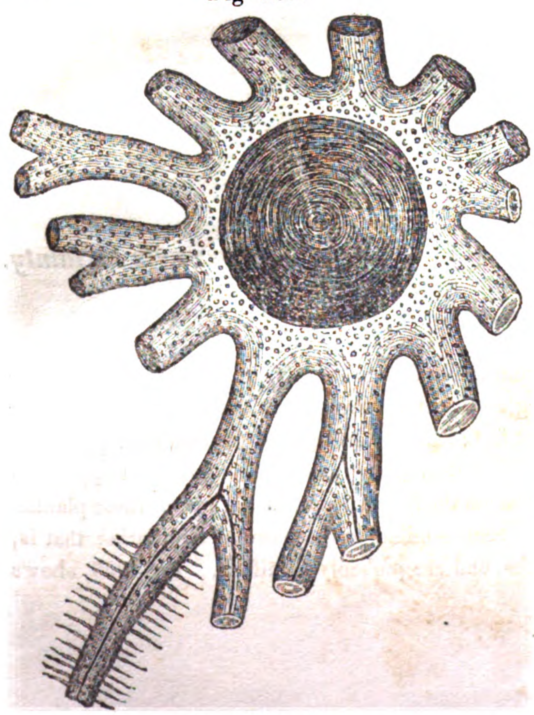


Ulodendron.

*Descrip.* Another very extraordinary fossil plant of the coal formation, is called Stigmaria. It consists (Fig. 225,) of a dome shaped center, three or four feet in diameter, from which proceeded branches 20 or 30 feet long, covered with tubercles, to which were attached cylindrical succulent leaves. It was probably an aquatic plant, which floated in the water, or trailed in swamps. It is thought to have been dicotyledonous.

*Descrip.* Another remarkable and beautiful tribe of plants, not unfrequent in the coal formation, had whorled leaves, like the flower of the Aster: hence one genus is called Asterophyllites. Fig. 226, shows one of these from the coal mine in Mansfield, Massachusetts, and has been already described.

Fig. 225.



Stigmaria.

Fig. 226.

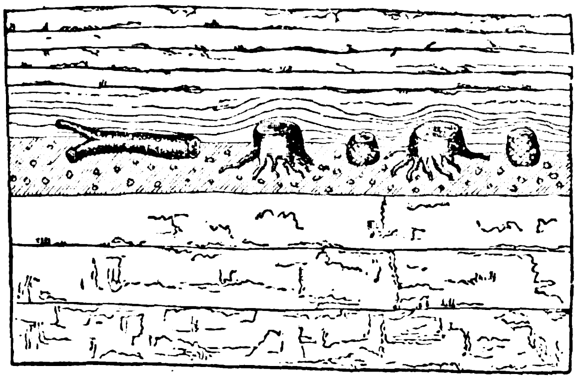
Annularia.

## *Coniferæ and Cycadeæ.*

*Descrip.* Sometimes the trunks of these gigantic trees, as well as some of the other plants that have been described, are found standing erect, rarely in the very place where they grew: but generally they appear to have been transported, and to have assumed an upright position by the greater specific gravity of the roots. Fig. 227, shows the stumps of an ancient forest of Coniferæ, with the roots imbedded in the black vegetable mould in which they grew; the whole being now converted into stone. The section was taken in the Isle of Portland, Eng.

Fig. 227.

Calcareous Slate.
Buhrstone
Dirt Bed.
Portland
Stone



*Subterranean Forest: Isle of Portland.*

*Descrip.* The Cycadeæ are a remarkable family of plants, occupying an intermediate place between Palms, Ferns, and Coniferæ; filling up an important link between dicotyledonous, monocotyledonous, and acotyledonous vegetation. Only two genera and 22 species are known as now living upon the globe. But during the deposition of the rocks above the coal, they formed a large part of the vegetation. For out of 70 species of land plants found fossil, during this period 29 species are cycadeæ, referable to 4 genera. They have lately been found also in the coal formation. The living species mostly grow in tropical climates. Fig. 228, represents a living species of these plants.

*Rem.* The great size of many fossil plants and the vast accumulations of carbonaceous matter in the coal formation, render it probable that the vegetation of the early periods of the globe was far more abundant than at the present day. Yet as the trees were mostly without flowers, and unenlivened by the presence and voices of any vertebral animals, the landscape must have presented a very uniform and sombre though imposing aspect: better adapted to a state of preparation for the higher orders of animals, than for their actual existence: better adapted to prepare fuel for man, than for his happy dwelling.

### ANIMALS.

### 1. *Radiated Animals.*

*Descrip.* The number of zoophytes in a fossil state is very large; and in almost every case, they differ specifically, and frequently generically, from existing species. I shall notice those, chiefly that are most unlike such as now live on the globe.

Fig. 228.

*Cyclas Revoluta.*

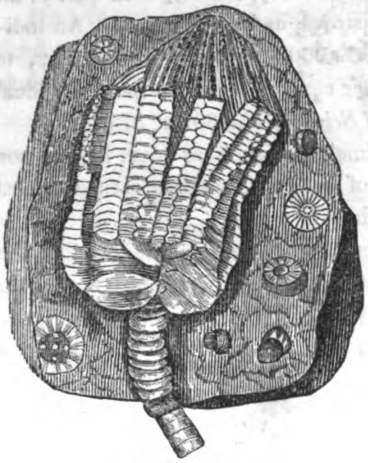
## *Crinoideans, or Encrinites.*

*Descrip.* The two genera that have attracted most attention are the ***Encrinites moniliformis*, *or Lily Encrinite*, *or Stone Lily*, *and the Pentacrinus*.** The former consists of a vast number of little joints, or bones, forming a column, (which may be called the vertebral column, although these animals are invertebral,) for the support of a cup like body, containing the viscera, and from whose margin proceed five articulated arms, divided into tentaculated fingers, more or less numerous, surrounding the mouth.—The animal was fixed at the bottom of the ocean, or to a piece of wood, and merely moved as far as it could reach by bending its very flexible column, which was admirably fitted for this purpose. The number of little bones, or joints, composing the head alone of this species, is estimated at 26.000. These bones are perforated and are used sometimes for rosaries. This animal relic is shown in Fig. 229.

*Descrip.* The stem of the Encrinite was circular, but that of *Pentacrinite* pentagonal. The latter also had usually a greater number of side arms and of joints. One of the most remarkable species was the *Briarean Pentacrinite*, (Pentacrinus Briareus) so called on account of the great number of its hands or tentacula. The bones in its fingers and tentacula, amount at least to 100,000 : and those of the side arms, to at least 50,000 more. And since each bone must have had two sets of muscular fibres for contraction and expansion, these bundles of fibres in the whole animal must have been as many as 300,000. This vastly exceeds the muscular apparatus in any other animal. What a contrast to man, whose bones are only 241, with 540 muscles!

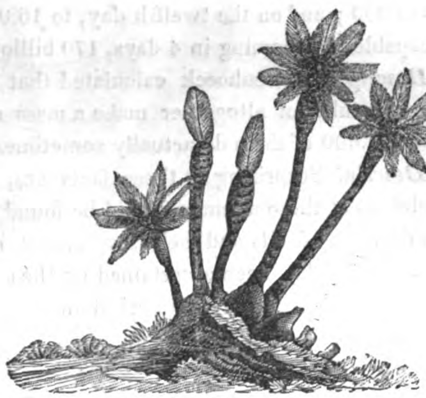
Fig. 230, shows another genus of this family, the *Apiocrinites* or *Pear Encrinite*. It is represented as restored, and situated as if in the water.

Fig. 229.



*Lily Encrinite.*

Fig. 230.



*Pear Encrinite.*

*Descrip.* *Polypi*, *Polypifers*, or *Polyparia*, are minute radiated animals that have the power of secreting carbonate of lime, and thus of building up large stony structures from the bottom to the surface of the ocean. They swarm in immense numbers in the seas of tropical climates, and form coral reefs which sometimes extend hundreds of miles. They seem to have existed in all ages, and to have formed similar deposits, which are now ranked among the limestones. Figs. 231, 232, and 233, show several living species of these animals as they are attached to their stony habitations.

Fig. 231.

*Polyparia.*

Fig. 232.

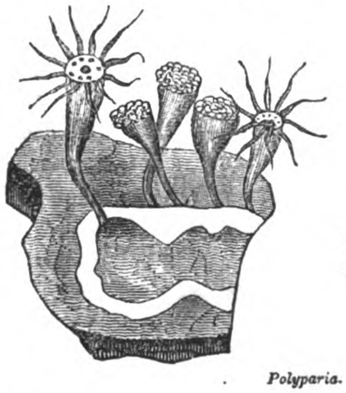


Fig. 233.

*Polyparia.*

## *Infusoria.*

*Descrip.* These animals are not discernible, with a few exceptions, but by powerful microscopes: and as they usually occur in some sort of infusion, they have been called ***Infusoria;*** though they generally go by the name of ***Animalculæ.*** The recent astonishing discoveries of Ehrenberg, a Prussian naturalist, have given a new aspect to this department of animated nature, even in a geological point of view. He has described 722 living species, which swarm almost everywhere, even in the fluids of living and healthy animals, in countless numbers.

*Descrip.* Formerly they were thought to be the most simple of all animals in their organization: to be in fact little more than mere particles of matter endowed with vitality; but he has discovered in them mouths, teeth, stomachs, muscles, nerves, glands, eyes, and organs of repro-

duction. Some of the smallest animalculæ are not more than the 24,000th of an inch in diameter; and the thickness of the skin of their stomachs, not more than the 50.000.000th part of an inch. In their mode of reproduction they are viviparous, oviparous, and gemmiparous. An individual of the Hydatina senta increased in ten days to 1.000.000: on the eleventh day, to 4.000.000; and on the twelfth day, to 16.000.000. In another case he says that one individual is capable of becoming in 4 days, 170 billions! *Am. Journal of Science, Vol.* 35. *p.* 372.

*Descrip.* Leuwenhoeck calculated that 1.000.000.000 animalculæ, such as occur in common water, would not altogether make a mass so large as a grain of sand; Ehrenberg estimates that 500.000.000 of them do actually sometimes exist in a single drop of water.

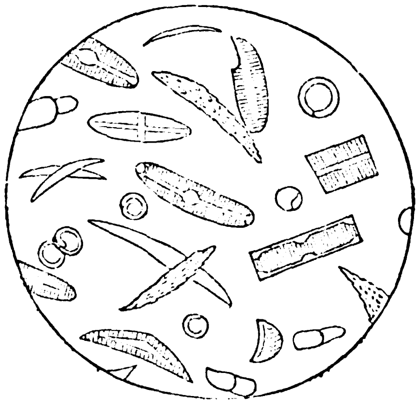
*Descrip.* Surprising as these facts are, it will perhaps seem still more incredible, that the skeletons of these animals should be found in a fossil state, and actually constitute nearly the whole mass of soils and rocks several feet in thickness, and extending over areas of many acres. Yet this too has been ascertained by the same acute Prussian naturalist. The following formations, he says, are of this description.

| | | |
|---|---|---|
| | 1. Bog Iron Ochre. <br> 2. *Kieselguhr*, a siliceous incrustation, from hot springs. | Alluvial. |
| | 3. *Polierschiefer*, Polishing Slate, a variety of Tripoli, or rotten stone. <br> 4. The Semi-opal of the Polierschiefer. | Tertiary. |
| Probably of the same nature. | 5. Semi-opal of the Dolerite. <br> 6. Precious Opal of the Porphyry. <br> 7. Flint of the Chalk. | Secondary and Primary. |

*Descrip.* Some of the above substances occur in large quantity. The polishing slate for example, at Bilin in Germany, forms a bed 14 feet thick, and the eatable infusorial earth near Lunebourg, a bed above 20 feet thick. Yet it would take 41.000 millions of these skeletons to make a cubic inch; their weight being only 220 grains! A single shield or *carapace*, weighs about the 187 millionth part of a grain!

*Descrip.* In New England and New York, the siliceous marl already described as occurring beneath peat in swamps, has been recently shown by Prof. J. W. Bailey, of West Point, to be almost entirely made up of the fossil skeletons of Infusoria, belonging to the family of Baccillariæ: some of which appear to be identical with those found by Ehrenberg in Germany. It is the *Bergmehl*, or *mountain meal*, of the Germans, and is frequently called *fossil farina*. Fig. 234, shows a group of these fossil skeletons, sketched by Prof. Bailey, as they appear when diffused in water, under the microscope.

Fig. 234.



*Fossil Infusoria.*

*Descrip.* Of 80 species of fossil infusoria discovered by Ehrenberg, nearly one half belong to

extinct species. Those in the recent strata, are all fresh water animals; but those in the chalk, are marine. *London and Edinburgh Philosophical Magazine for May* 1839. *p.* 377.

*Descrip.* "The fossil animalcule from iron ochre is only the one twenty first part of the thickness of a human hair; and one cubic inch of this ochre must contain one billion of the skeletons of living beings." *Wonders of Geology, Vol.* 2. *p.* 689.

## 2. Articulated Animals.

*Descrip.* The animals of this class are distinguished by having envelopes connected by annulated plates or rings.

*Descrip.* Until recently, no insects had been discovered lower in the rocks than the Oolite: but two species of Coleoptera, and one of Corydalis, have of late been disinterred in the coal formation. *Buckland's Bridgewater Treatise, Vol. I. p.* 409. Not less than 25 species occur in the Oolite, and 244 species in a fresh water formation of the Tertiary group. *Bronn's Lethæa Geognostica, p.* 811.

### Arachnidans, or Spiders and Scorpions.

*Descrip.* The scorpion has recently been found in the coal formation in Bohemia, by Count Sternberg; and is the first example of this animal in a fossil state. Spiders have not been found lower than the Oolitic series, where only two species are recognized; but in the freshwater tertiary several species occur.

### Crustaceans.

*Descrip.* Crustaceous animals are not common in the rocks; yet the King Crab (*Limulus*,) so abundant on the coast of New England, has been found in the coal formation, and also in the Oolite, where other animals of this family occur. But the most remarkable animal of this class is extinct, viz.

### The Trilobite.

*Descrip* This singular animal, which is found in the older fossiliferous rocks, in all the northern parts of Europe, in North and South America, and at the Cape of Good Hope, was long confounded with insects. But it was at length ascertained that it corresponded most nearly to the living genera of Crustaceans, the Serolis, Limulus, and Branchipus. Figs. 235, 236, represent two genera of trilobites, out of the ten genera and 52 species that are known. It will be seen that this animal is composed of a shield covering the anterior part of the body, while the abdomen has numerous segments which fold over one another like those on a lobster's tail. By this arrangement some of the species had the power to roll themselves up like the wood louse, or the armadillo, and thus of defending themselves against enemies. These animals were sometimes 5 or 6 inches long, and are divided by longitudinal furrows into three lobes; and hence their name. They seem to have been destitute of antennæ, and their legs, which were soft, and which answered the purpose of legs and wings, have disappeared.

*Descrip.* Trilobites abounded among the earlier inhabitants of the globe, being most common in the graywacke. A few species occur in the carboniferous strata; above which, not a trace of them has been discovered. In the carboniferous strata they are accompained by the Limulus. This latter also occurs in the oolitic group, with other Crustaceans of a higher order.

*Descrip.* Perhaps the most curious fact respecting the trilobite is the discovery of their eyes, which are sometimes perfectly preserved. It is well known that the eyes of crustaceous animals, like those of insects, are made up of a vast number of facets, or lenses, placed at the end of tubes, which are arranged side by side, so as to produce a radiating mass of eyes, which being generally of a hemispherical or conical form, and sometimes elevated from the head on a stem, enable

the animal to see in every direction; although their eyes have no motion. In some insects the number of these lenses in both eyes, as in the house fly, is 14.000: in other cases (the dragon fly,) 25.000: in others, (the butterfly,) 35.000: in others (the Mordella,) 50.000. But in the trilobite they amount only to about 800. The whole mass is of conical shape as is shown in Fig. 237.

Fig. 235.

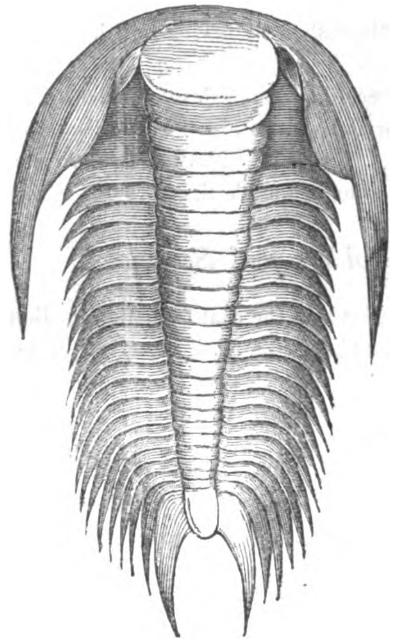
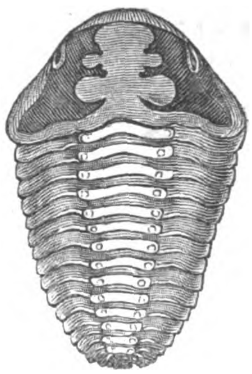


Fig. 236.

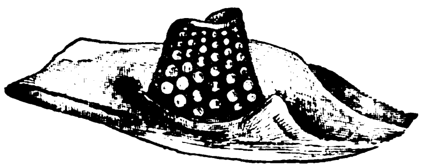


## 3. *Mollusca.*

### *Chambered Shells.*

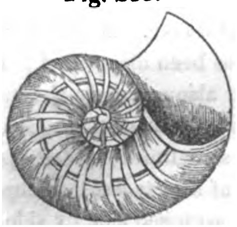
***Descrip.*** These are univalve shells, which are divided into numerous compartments, or chambers, by cross partitions; as is shown in Fig. 238, which is a section of the common ***Nautilus pompilius.*** These partitions are all perforated by what is called the ***siphuncle***, which consists mostly of a membrane, having the form of a tube, and being so firmly fastened to the partitions that no air can pass by it into the chambers. The animal resides in the outer chamber, and is connected with the others only by the siphuncle.

Fig. 237.



*Eyes of the Trilobite.*

Fig. 238.



*Nautilus.*

## *Ammonites.*

*Descrip.* With the exception of one or two species of Nautilus, all the larger species of multilocular or chambered shells have disappeared from the earth, although in early times they were very numerous and widely diffused, and often of enormous size. They resemble the Nautilus in general form and structure, although generically different; and they are sometimes found more than four feet in diameter. Figs. 239, 240, represent two species of Ammonites.

Fig. 239.

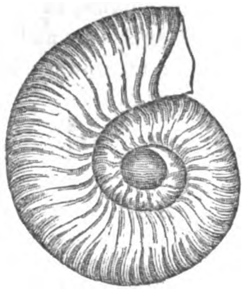
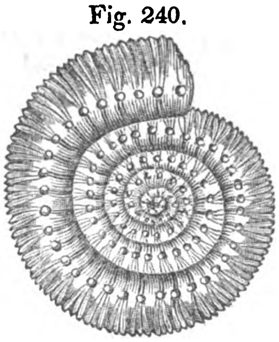


Fig. 240.



*Ammonites.*

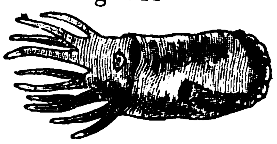
*Details.* Brochant enumerates 270 species of ammonites: Phillips mentions 274, which he distributes as follows: In Graywacke 17: In the Carboniferous system 33: In the Saliferous system 3: In the Oolitic system 164: In the Cretaceous system 57: In the Tertiary Strata, o? *Treatise on Geology, Vol.* 1. *p.* 83.

*Descrip.* It is well ascertained that in some chambered testacea, the shell is contained within the animal; as in the *Spirula Peronii*, Fig. 241. This appears to have been the case with several extinct genera, as the Orthoceratite, Lituite, Baculite, Hamite, Scaphite, Turrilite, Nummulite, and Belemnite.

## *Orthoceratite.*

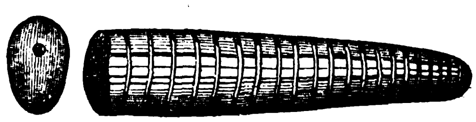
*Descrip.* As its name implies, this was a strait shell divided by transverse septa into chambers, of which nearly 70 have sometimes been counted. It has been found a yard in length, and half a foot in diameter; forming a *float*, which would have been sufficient for an animal far larger than any existing cephalopod. Fig. 242, shows the shell of an orthocera with one of the septa.

Fig. 241.



*Spirula Peronii.*

Fig. 242.



*Orthocera.*

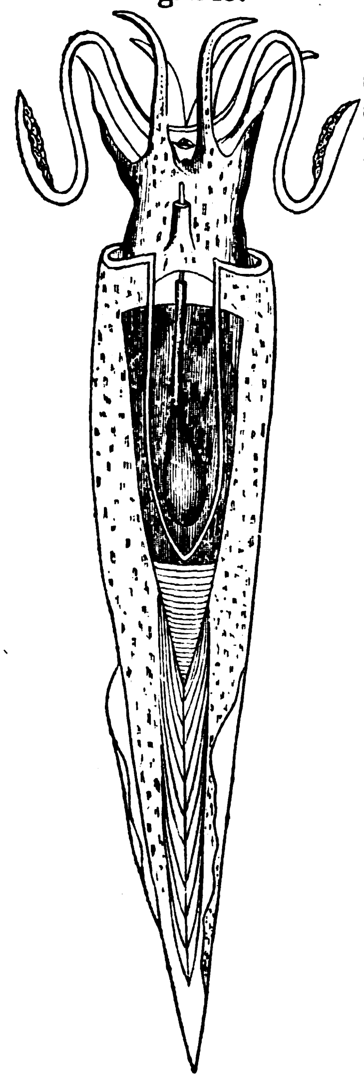
## *Belemnite.*

*Descrip.* This internal shell resembled a conical arrow, with a cavity of similar shape, in which was a thin horny sheath, and within this a thin conical chambered shell, or *alveolus*. It was provided, also, with an ink bag, like the living Sepia, or Cuttle Fish, as a defence against enemies, or rather, as a means of making good their retreat. These shells are found only in the oolite and the chalk, and 83 species have been described.

Fig. 243, shows an imaginary restoration of the Belemnosepia, as made by Dr. Buckland,

(*Bridgewater Treatise, Vol.* 2. *plate* 44. *fig.* 1.) exhibiting the animal with the internal shell and ink bag.

Fig. 243.



## *Nummulites.*

*Descrip.* These extinct shells are so called from their resemblance to money. They are generally of very diminutive size, and belong to what are called the *foraminated polythalamous*, or many chambered shells. They are chiefly remarkable for their vast numbers, constituting often almost the entire mass of whole mountains, in the tertiary and newer secondary limestones. The Sphinx and some of the pyramids of Egypt are composed of nummulitic limestone. Fig. 244, exhibits a species of nummulite.

Fig. 244.

*Nummulite.*

## *Loligo or Cuttle Fish.*

*Descrip.* It is well known that the Cuttle fish (Sepia or Loligo), is provided with a bag of ink within its body, from which the Sepia used in painting is obtained; and also with an internal bone, or in some species, a mere thin cartilaginous substance like horn, that resembles a quill. Both the ink and the pen of the Loligo have recently been discovered in a fossil state, in England. *Buckland's Bridgewater Treatise, Vol.* 1. *p.* 303.

*Rem.* It is a very curious fact, that a substance so easily destroyed as ink, should have been so perfectly preserved in the lias limestone of Lyme Regis, that after thousands and perhaps ten thousands of ages, it can be extracted, and the paint formed from it cannot be distinguished from the best which artists now prepare.

## *Bivalve Shells, mostly extinct.*

*Descrip.* Of the Terebratula, (Fig. 245,) 30 species have been found in the graywacke; 21 in the carboniferous system; 14 in the new red sandstone; 49 in the oolite; 57 in the chalk; 18 in the tertiary strata, and 12 among living molluscs.

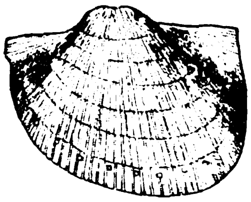
*Descrip.* Of the Producta, (Fig. 246,) 21 species are found in the graywacke; 36 in the carboniferous system; and in the new red sandstone, 7; none above.

Of the Spirifer, (Fig. 247,) which shows the spiral appendages within the shell as well as the external appearance, 37 species are found in the graywacke, 48 in the carboniferous system, and 7 in the red sandstone: none above.

Fig. 245.

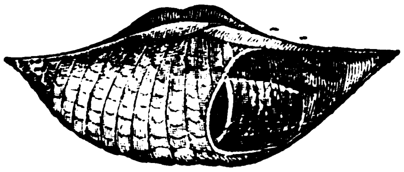
*Terebratula.*

Fig. 246.



*Producta.*

Fig. 247.



*Spirifer.*

## VERTEBRAL ANIMALS.

*Descrip.* This extensive division of the animal kingdom embraces those animals whose organization is the most perfect, with man at their head. A cranium, and vertebral column, which encloses the principal part of the nervous system, and a regular skeleton, covered by muscles, constitute the principal anatomical distinctions between this class and the three that have already been considered. It is divided into four well marked tribes: 1. Mammalia, 2. Birds, 3. Reptiles, 4. Fishes.

### *Fishes.*

*Descrip.* The number of living species of fish now known, amounts to about 8000: and the number of fossil species to more than 850. *Buckland's Bridgewater Treatise, Vol.* 1. *p.* 267.

*Descrip.* Fishes are found in all the great rock formations from the graywacke upwards:—a fact which is not true of any other class of vertebral animals; and therefore, the history of fossil fishes becomes of great importance.

*Prin.* Not one species of fish has yet been found that is common to any two of the great geological formations; or is now living in the ocean.

*Prin.* Fossil fishes do not change insensibly as we pass vertically from one formation to another, but abruptly; and these changes occur simultaneously with those in other classes of organic remains.

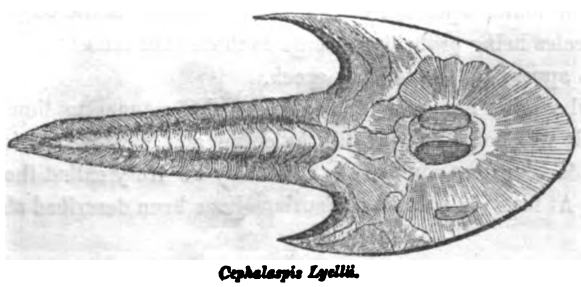
*Inference.* Hence the conclusions that have been made from the history of other organic remains, are confirmed by this new branch of palæontology.

*Descrip.* Below the chalk not even any genus is found that embraces any living species: those of the carboniferous strata disappear with the deposition of the new red sandstone: those in the oolite, introduced after the epoch of the new red sandstone, suddenly vanish with the appearance of the chalk. Two thirds of those in the chalk and one third of those in the lower tertiary strata, belong to genera no longer existing. *American Journal of Science, Vol.* 30. *p.* 40, 41.

*Prin.* In some of the groups of animals preserved in the rocks, certain types of organization predominate; and such was the correlation between different species, that they often conform more or less to the prevailing type.

*Examples.* 1. In the older fossiliferous rocks, tribolites occur in great quantities; and in the old red sandstone is found a genus of fishes approaching in form to the tribolites. Fig. 248, exhibits a species of this kind.

Fig. 248



*Cephalaspis Lyellii.*

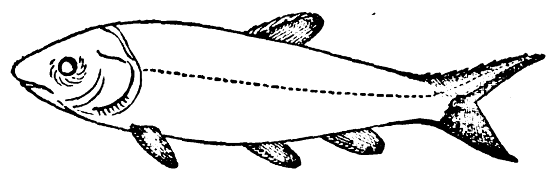
*Ex.* 2. In the secondary strata, during the deposition of the oolite, especially, saurian reptiles prevailed exceedingly. And Agassiz has described 17 genera of sauroid fishes, found in all the formations from the carboniferous upward, except the tertiary: but only two generar emain among living fishes: viz. the *Lepidosteus osseus* or Bony Pike of North America; of which there exist five species and the *Calypterus* of two species. Some of these sauroid fishes in the rocks were of enormous size; their teeth being larger than those of the living crocodile.

## *Sharks.*

*Descrip.* These fishes occur in a living state all over the globe; and there seems to have been no period in geological history in which they did not prevail. More than 150 species have been found fossilized.

*Descrip.* Another singular variety of fish is found in all the strata below the lias, distinguished by their heterocercal or unsymmetrical tails; that is, by tails whose upper lobe extends much the farthest by the prolongation of the vertebral column. Fig. 249. represents one of these fishes of the genus Palæoniscus. Most living fishes have homocercal, or equally bilobate tails.

Fig. 249.



*Palæoniscus.*

## *Coprolites.*

*Descrip.* The fecal remains of fishes and other animals, which have been found frequently in several formations, have been called Coprolites. Sometimes they are found detached and sometimes in the body of the animal; and the information derived from them, as to the food, habits, &c. of the animals to which they belong, is of great importance.

## *Reptiles.*

*Def.* The remains of Reptiles in the rocks are perhaps more remarkable, and have excited more astonishment and incredulity, than those of any other class of animals. This is especially true of that tribe called *Saurians:* which, in popular language, are nearly the same as *Lizards:* though the Lizards properly so called, embrace only two genera of Lacerta. *Cuvier's Regne Animal, Tome 2.p.* 30.

## *Saurians.*

*Descrip.* The most remarkable feature of the fossil saurians is their great size, as compared with those species still found upon the earth. The crocodile is the only exception to this remark; the living species being probably as large as those that are extinct. But the true crocodiles did not begin to appear till the tertiary epoch.

*Descrip.* No fossil saurian has been found below the magnesian limestone of the new red sandstone system. It was not, however, till the oolite and wealden period that their number was large, and their development complete. That may be truly called the *Age of Reptiles;* or the *Saurian Reign.* At least 40 species of Saurians have been described already from the oolitic

group, and 11 species from the Wealden Rocks. In all the formations there have been found about 80 species.

*Def.* Dr. Buckland divides the fossil Saurians into the Marine, the Terrestrial, the Amphibious, and the Flying. *Bridgewater Treatise, Vol. I. p.* 165.

## *Ichthyosaurus.*

*Descrip.* This animal, sometimes more than 30 feet long, and of which 7 or 8 species are known, had the snout of a porpoise, the teeth of a crocodile, (sometimes amounting to 180,) the head of a lizard, the vertebræ of a fish, the sternum of an Ornithorhynchus, and the paddles of a whale: uniting in itself a combination of mechanical contrivances which are now found among three distinct classes of the animal kingdom. One of its paddles was sometimes composed of more than 100 bones; which gave it great elasticity and power, and enabled the animal to urge its way through the water with a rapid motion. Its vertebræ were more than 100. Its eye was enormously large: in one species, the orbital cavity being 14 inches in its longest direction. This eye also had a peculiar construction to make it operate both like a telescope and a microscope: thus enabling the animal to descry its prey in the night as well as day, and at great depths in the water. The length of the jaws was sometimes more than 6 feet. Its skin was naked, some of it having been found fossil: its habits were carnivorous, its food, fishes and the young of its own species; some of which it must have swallowed several feet in length. This fish-like lizard was an inhabitant of the ocean. Fig. 250, exhibits a restored Icthyosaurus, by Mr. Hawkins. *Memoirs of Ichthyosauri and Plesiosauri, extinct Monsters of the ancient earth. By Thomas Hawkins, Esq. Folio with* 28 *plates.*

Fig. 250.

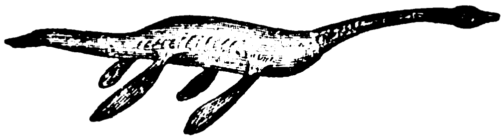
*Ichthyosaurus.*

## *Plesiosaurus.*

*Descrip.* This animal, of which 6 or more species have been found, has the general structure of the Icthyosaurus. Its most remarkable difference is the great length of the neck; which has 33 vertebræ: a larger number than in any known animal: those of living reptiles varying from 3 to 6, and those of birds from 9 to 23.

The largest perfect specimen yet found is 11 feet long; with about 90 vertebræ. Its paddles were proportionally larger than in the Ichthyosauri. It was carnivorous; an inhabitant of the ocean, or rather of bays and estuaries: where it probably used its long neck for seizing fish beneath, and perhaps flying reptiles, above the waters. Fig. 251, exhibits a restoration of one of the most remarkable species, the *P. Dolichodeirus*, by Mr. Hawkins.

Fig. 251.



*Plesiosaurus.*

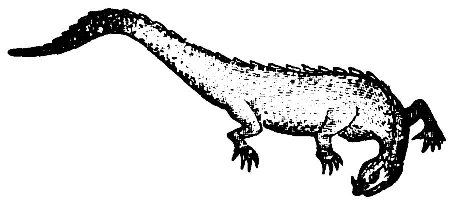
*Remark.* According to Dr. Harlan's Medical and Physical Researches, Ichthyosauri and Plesi-

osauri have been found in the secondary rocks of the United States. He has also described another gigantic reptile from this country under the name of *Batrachiosaurus Missouriensis*. *Mining Review for January*, 1839, *p*. 10.

## *Iguanodon.*

*Descrip*. This animal approaches nearest in its structure, especially that of the teeth, to the living Iguana: a reptile of the warmer parts of this Continent; and hence its name; signifying an animal with teeth like the Iguana. Its average length could not have been less than 70 feet, and Dr. Mantell thinks some individuals must have exceeded 100 feet: Circumference of the body, 14 1-2 feet: length of the tail, 52 1-2 feet: do. of the hind foot, 6 1-2 feet: circumference of the thigh, more than 7 feet! The form of the teeth shows it to have been herbivorous, like the living Iguana. It had a horn 4 inches long upon the snout, like some species of Iguana. Fig. 252, which represents an Iguana, will probably give some idea of the Iguanodon.

Fig. 252.

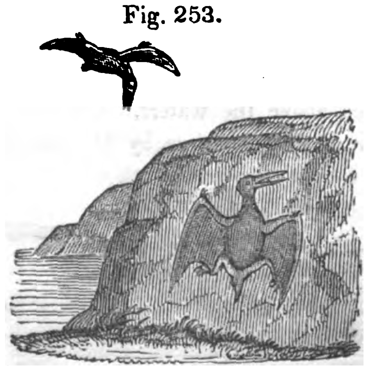


*Iguana.*

## *Pterodactyle.*

*Descrip*. This animal had the head and neck of a bird, the mouth of a reptile, the wings of a bat, and the body and tail of a mammifer. Its teeth, as well as other parts of its structure, show that it could not have been a bird; and its osteological characters separate it from the tribe of bats. But in many respects it had the characters of a reptile. The outer toe of its fore feet was enormously elongated, to furnish support, it is probable, for a membranous wing. By this means it was doubtless able to fly like the bat; while the fingers with claws projecting from their wings, enabled it to creep or climb. When its wings were folded, it could probably walk on two feet; and it is most likely also, it could swim. Its eyes were enormously large; so that it could seek its prey in the night. It probably fed on insects chiefly; though perhaps, also, it had the power of diving for fish. Eight species, from the size of a snipe to that of a cormorant, have been found in the oolite and lias in England, and on the continent of Europe, at Solenhofen. Fig. 253, shows several of these animals restored.

Fig. 253.



*Pterodactyle.*

*Remark*. "Thus," says Dr. Buckland, "like Milton's fiend, all qualified for all services, and

all elements, the Pterodactyle was a fit companion for the kindred reptiles that swarmed in the seas, or crawled on the shores of a turbulent planet.

> "The Fiend,
> O'er bog, or steep, through straight, rough, dense, or rare,
> With head, hands, wings, or feet, pursues his way,
> And swims or sinks, or wades, or creeps, or flies."—*Paradise Lost, Book 2, Line* 947.

"With flocks of such-like creatures flying in the air, and shoals of no less monstrous Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic Crocodiles and Tortoises, crawling on the shores of the primeval lakes and rivers; air, sea, and land must have been strangely tenanted in these early periods of our infant world." *Bridgewater Treatise, Vol. I. p.* 224.

## *Birds.*

Twenty species of birds have been found in diluvium; ten in the tertiary strata, and recently one species of Grallae, or Waders, in the wealden formation: and these are all the fossil relics of this order of animals yet discovered. The tracks of more than 20 different species of animals have already been described in another place.

### MAMMALIA.

*Descrip.* There is reason to believe that the Marsupial Mammalia appeared earlier on the globe than any other animals of this class. For Dr. Buckland has found two undoubted species of Marsupials in the oolite in England: and the tracks of another species of a similar animal in red sandstone, near Hildburghausen in Saxony, as well as in two places in England, have recently been described; as will be more fully detailed in another place.

*Descrip.* With the above exception, all the other fossil mammalia occur in the tertiary strata and diluvium. In the Eocene tertiary, as many as 50 species have come to light. Cuvier described 78 species in his great work, the *Ossemens Fossiles;* 49 of which are extinct: and since that time, the number has been increased to nearly 200.

*Descrip.* Among these fossil animals, are many of existing genera, and so nearly related to existing species, that a particular description will be unnecessary. Such are the fossil species of the Rhinoceros, Hippopotamus, Hog, Cat, Glutton, Horse, Ox, Deer, Bear, Hyæna, Weazel, Hare, Rabbit, Rat, Mouse, &c. In general, however, the fossil species are of a larger size than those now living; indicating a warmer climate when they were upon the globe.

*Descrip.* The history of bone caverns and fissures, as described by Dr. Buckland in his splendid work, entitled *Reliquiæ Diluvianæ*, deserves a more extended notice than can here be given. From a careful examination of these osseous caverns, by Dr. Buckland, it appears that some of them, as that of Kirkdale, Kent's Hole, &c. in England, were the residence of hyænas for a long time previous to the Historic Period; and that these animals dragged in thither great quantities of bones of other animals on which they fed. This is proved by the broken and gnawed state of the bones, and by the great quantity of coprolites belonging to the hyæna found in the caverns. Other caverns appear to have been the abodes of bears for a long period: as those of the limestones of central Germany. In one of these, the cave of Kuhloh, more than 500 cubic feet of black animal dust, impressively denominated the *dust of death*, were found, resulting from the decomposition of bears; which must have required at least 2500 of these animals! The bones of the Osseous Breccia, found in fissures in Somersetshire in England, and on the the northern shores of the Mediterranean, belong mostly to animals that fell into fissures that were afterwards filled with diluvial detritus. *Reliquiæ Diluvianæ, p.* 137, *and* 148. *London,* 1823. *De la Beche's Manual of Geology, p.* 181.

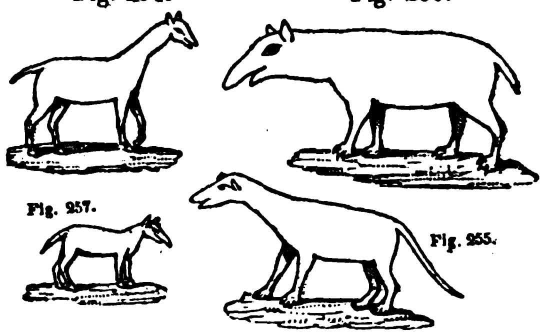
*Descrip.* Osseous breccias have been found in Australasia, containing bones of the kangaroo,

wombat, dasyurus, koala, halmaturus, elephant, hypsiprimnus, &c. most of which are animals living in that country.

## *Early Pachydermata.*

*Descrip.* In the older tertiary strata around the city of Paris, Baron Cuvier has brought to light more than 40 extinct quadrupeds, many of them allied to the modern pachydermata, or thick skinned animals. Fig. 254, exhibits the form of the *Anoplotherium gracile*, which was of the size and form of the gazelle, living like the deer and the antelope. Fig. 255, is the *Anoplotherium commune;* an animal about the size of the wild boar, with the means of swimming with facility. Fig. 256, is the *Palæotherium magnum*, of the size of the horse, but more thick and clumsy. Probably it had a trunk. Fig. 257, is the *Palæotherium minus*, of the size of the roebuck.

Fig. 254. Fig. 256.




254 *Anoplotherium gracile.* 255 *Anoplotherium commune.* 256 *Palaeotherium magnum.* 257 *P. minus.*

## *Mammoth, or Fossil Elephant.*

*Descrip.* Two species of living elephant are known; the Asiatic, or Indian, which extends only to the 31st degree of north latitude: and the African, which occurs as far south as the Cape of Good Hope. A third species is found in a fossil state; especially in the northern parts of Asia and Europe; as well as America. It is this extinct species that goes by the name of *mammoth*—an Arabic word (*behemoth,*) signifying elephant. Fig. 258, exhibits the skeleton of the remarkable specimen found encased in frozen mud on the shores of the arctic ocean, in Siberia, with its softer parts preserved, as has been already described. This skeleton is now deposited in the Museum of Natural History in St. Petersburgh. Its length is 16 feet; and its height 9 feet. Its hair, of which 30 pounds were preserved, consisted of black bristles, 15 inches long, mixed with wool of a reddish brown color.

Fig. 258.

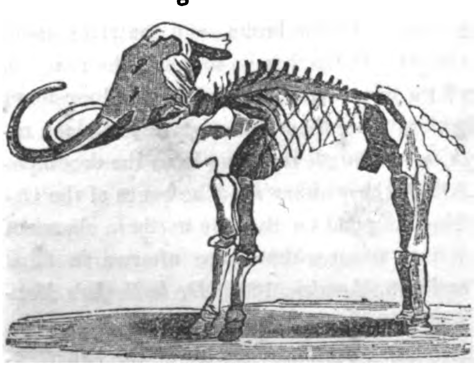


Fig. 259.

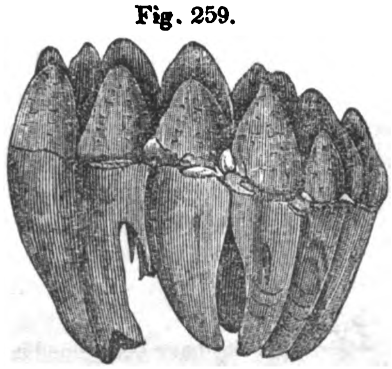
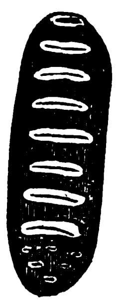


Fig. 260.



## *Mastodon.*

*Descrip.* Although the mastodon is frequently called the mammoth in this country, where the remains of the largest species are abundant, yet it differs generically from the elephant in the form of its teeth; as may be seen in Figs. 259 and 260 above. Fig. 259 is a side view of the grinder of the Mastodon, and Fig. 260, represents the flat surface of the Mammoth's grinder.

*Descrip.* No less than seven species of the mastodon have been discovered in a fossil state; viz. three in Europe, two in South America, one in the United States, and one in India. The largest species, *M. maximus*, has been found in almost every part of the United States; though most abundantly in the Salt Licks of Kentucky, Ohio, &c. The most easterly point where the bones of these animals have been found, is Berlin in Connecticut. An almost entire skeleton has been put up in the Museum of Mr. Peale in Philadelphia, which is 15 feet long, and 11 feet high. This was found in Orange County, New York. The most remarkable locality in this country is at the Big Bone Lick in Kentucky; where a vast number of bones of various extinct animals are imbedded in dark colored mud and gravel, which appears to have been formerly the bottom of a marsh. This spot has been examined by William Cooper, Esq. with his usual discrimination and accuracy; and he is of opinion that the deposit containing the bones is to be regarded as diluvial. He estimates that the bones of 100 mastodons, 20 elephants, 2 oxen, 2 deer, and one megalonyx, have already been carried from this spot.

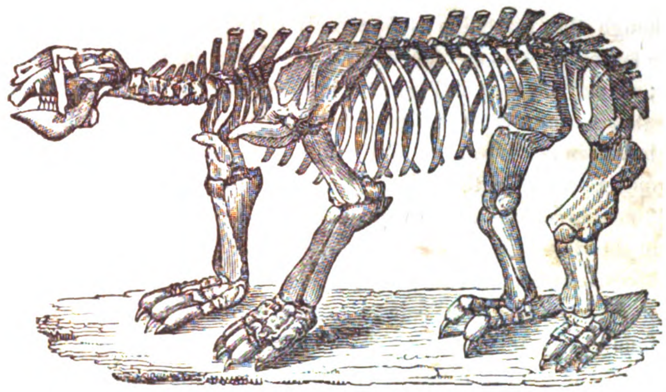
## *Rhinoceros, Hippopotamus, Hyæna, Horse, Ox, Deer, Sivatherium, Monkey, Camel, &c.*

*Descrip.* Most of these animals in their fossil state, differ so little from the existing species, that they need not be particularly described in this work. They are generally, however, of a larger size than the living species. In India have been found the remains of a gigantic species of monkey and of a camel. Another species of monkey has also been discovered in tertiary deposits in France: so that the important fact seems now well established, that the animals approaching nearest to man in their structure, have been found in a fossil state. *Wonders of Geology, Vol. I. p.* 138 *and* 226.

## *Megatherium.*

*Descrip.* The Megatherium is an enormous extinct animal, which was once abundant in the vast plains or pampas of the same continent. They have been lately found by Mr. Darwin, over an extent of 600 miles, acompanied with bones and teeth of five other quadrupeds, some of them of a similar construction. Dr. Mitchell and Mr. Cooper have also described bones of this animal from the island of Skiddaway, on the coast of Georgia. *Buckland's Bridgewater Treatise, Vol. II. p.* 20. *Annals of N. Y. Lyceum, May,* 1824. It was larger than the rhinoceros, and its proportions were perfectly colossal. With a head and neck like those of the sloth, its legs and feet exhibit the character of an armadillo, and the ant eater. Its body was 12 feet long, and 8 feet high. Its fore feet were a yard in length, and more than 12 inches wide; terminated by gigantic claws. Across its haunches it measured five feet; and its thigh bone was nearly three times as thick as that of the elephant. Its spinal marrow must have been a foot in diameter; and its tail, at the part nearest the body, twice as large, or six feet in circumference! Its teeth were admirably adapted for cutting vegetable substances; and its general structure and strength seem intended to fit it for digging in the ground for roots on which it principally fed. Fig. 261, exhibits the entire skeleton of this animal, which exists in the museum at Madrid, in Spain. *Buckland's Bridgewater Treatise, Vol. I. p.* 139.

Fig. 261.



*Megatherium.*

## *Megalonyx.*

*Descrip.* This animal was first described by Mr. Jefferson, who mistook its characters. It was found in the nitre caverns of Virginia and Kentucky, and has since been discovered in other places. It was of the size of the ox, and appears to have been nearly related to the sloths.

## *Dinotherium.*

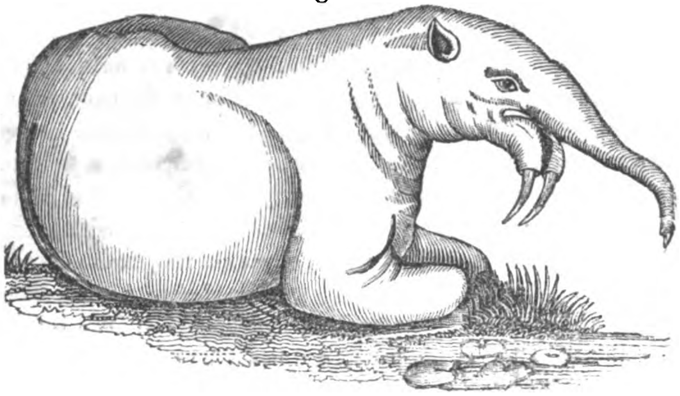
*Descrip.* Until recently the mammoth and the mastodon have been supposed the largest of all the terrestrial mammalia that have ever inhabited the earth: but they must give place to the Dinotherium, described by Cuvier as a gigantic tapir, but recently by Professor Kaup, a distinguished German naturalist, as a new genus between the tapir and the mastodon: and adapted to that lacustrine condition of the earth which seems to have been so common during the deposition of the tertiary strata. Its remains have been found in tertiary strata, in the south of France, in Austria, Bavaria, and especially in Hesse Darmstadt. Its length must have been as much as 18 feet. One of its most remarkable peculiarities consisted in two enormous tusks, at the anterior extremity of the lower jaw, which curved downwards, like those of the Walrus. Its general structure seems to have been adapted to digging in the ground; and for this purpose its feet as well as tusks, projecting a foot or two beyond the jaws which were four feet long, were intended. It lived principally in the water like the hippopotamus; and it probably used its tusks for tearing up the roots of aquatic vegetables, which, as is shown by its teeth, constituted its food. Dr. Buckland suggests also, that these tusks might have been useful as an anchor fastened into the banks of a river, while the body of the animal floated in the water and slept. They might have been useful also, to aid in dragging the body out of the water and for defence.

Fig. 262, is a sketch of the *Dinotherium giganteum* as restored by Prof. Kaup. *Buckland's Bridgewater Treatise, Vol. I. p.* 135. Another species, the D. Bavaricum, has been discovered.

## *Ichnolithology: or the History of Fossil Footmarks.*

*Descrip.* This singular branch of palæontology has but lately begun to attract the attention of geologists; since it is only within a few years that genuine examples of the tracks of animals in stone have been found. It is, indeed, and long has been the common belief, that such impressions are frequent; but the geologist usually finds that they are merely the effects of disintegration or aqueous action, by which the softer parts of the rock are more worn away than the harder parts. The following are all the well authenticated examples of fossil footmarks that have been discovered up to the present time.

Fig. 262.



Dinotherium.

*Descrip.* The tracks of tortoises were described in 1828, by Dr. Duncan, upon the new red sandstone of Scotland: those of Crustaceous animals on the Forest Marble of Bath in England, in 1831, by Mr. Scope: those of the Chirotherium upon the new red sandstone of Saxony in 1834; and about the same time, those in the valley of the Connecticut river, described in the third part of this Report. Those of the Chirotherium and of Saurian reptiles at the quarries of Storeton Hill in England in 1838: Those of animals with trifid feet, near Shrewsbury in England, in 1839, by Dr. Ward: and those of some singular bipeds in Saxony, not far from Leipsic, by Dr. Cotta, in 1839. The sketch, Fig. 263, will give an idea of the tracks of the Chirotherium at Hildberghausen in Saxony.

Fig. 263.

## 12. *General Inferences.*

*Remark* I have passed over several important inferences derived chiefly from palæontology, because they were not deducible from any one statement that has been made, and I thought it best to present them in the conclusion of this Section with a summary of the proof.

*Inference* 1. **The present Continents of the globe, (except perhaps some high mountains,) have for a long period constituted the bottom of the ocean, and have been subsequently elevated.**

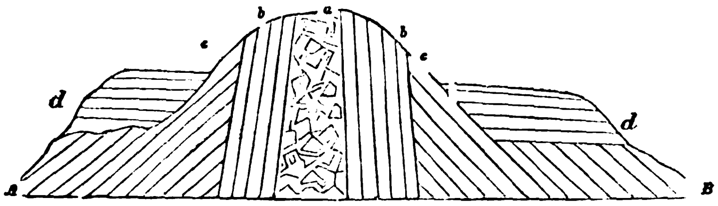
*Proof* 1. Two thirds at least of these Continents are covered with rocks, often several thousand feet thick, abounding in marine organic remains; which must have been quietly deposited, along with the sand, mud, and calcareous or ferruginous matter in which they are enveloped, and which could have accumulated but slowly. 2. The primitive regions of the globe bear marks of powerful abrasion by water from some cause no longer acting upon them; and which can be explained only by supposing the waters of the ocean to have flowed over them for a long period. 3. The secondary and primary stratified rocks are almost universally fractured and raised up at various angles, just as they would have been if lifted from the bottom of the ocean by a force acting beneath them. 4. Anticlinal ridges are so frequently found with a nucleus of unstratified rocks, as to point us to a sufficient cause, viz. volcanic agency, for the elevations that appear to have taken place.

*Remark.* This inference is to be regarded as probably the most important principle in geology, and as established on an immovable foundation.

*Inference* 2. **Different Continents, and different parts of the same Continent, appear to have been elevated at different epochs.**

*Proof.* Let A B, Fig. 264, represent a mountain ridge, with an axis (*a*) of unstratified rock. Upon *a* let the three systems of strata *bb*, *cc*, and *dd*, rest upon the axis, and upon one another, unconformably, and dipping at different angles, except *dd*, which suppose horizontal. Now it is obvious that the formations *cc*, and *bb*, must have been elevated previous to the deposition of *dd;* otherwise the latter would have partaken of the upward movement. And if there be no regular member of the series of rocks wanting, between *d*, and *c*, it is obvious that we thus ascertain the geological, though not the chronological epoch, when *cc*, was elevated. *cc*, however, is unconformable to *bb;* and therefore *bb*, was partially elevated before the deposition of *cc:* in other words, *bb* has experienced at least two vertical movements. Now this is a just representation of the actual state of things in the earth's crust; and hence by ascertaining the dip of the formations that are in juxta position, we ascertain the different epochs of elevation.

Fig. 264.




*Epochs of Elevation.*

*Facts.* By the application of these principles, it is found that the mountains of Europe have been elevated at no less than twelve different epochs; the oldest of which dates as far back as the time when the slates of Westmoreland were tilted up: and the most recent, (the principal chain of the Alps,) is said to be subsequent to the deposition of the tertiary strata.

*Inf.* 3. The convulsive movements by which systems of strata were elevated, appear to have been in most instances short, compared with the intervening periods of repose, during which successive formations were deposited.

*Inf.* 4. In many instances the rocks appear to have suffered one alternation or more of elevation and subsidence.

*Inference* 5. **From the phenomena of organic remains, it appears that the species of animals and plants now existing on the globe, could not, with a few exceptions, have been contemporaries with those found in the rocks.**

*Proof.* If they had been contemporaries, no reason can be given why the remains of the living species do not occur in the rocks; which, with the exception of a few hundred species in the more recent tertiary strata, is well known not to be the case. 2. Comparative anatomists decide from the structure of the extinct animals and plants, that they were intended for a climate and other physical circumstances so different from those now existing, that the organic beings adapted to the one, could not have endured the other. The period of the tertiary strata is the only exception: and even then, the climate appears to have been in high northern latitudes nearly as at present between the tropics.

*Inference* 6. Hence too we learn the mistake of those, who are in the habit of pronouncing very confidently that certain organic remains are petrifactions of existing animals or plants. For if they are obtained from the secondary rocks, the presumption amounts almost to certainty, that they cannot be the representatives of existing species.

*Examples.* Fossil trees are called oak, maple, hemlock, &c.: fibrous tremolite and some varieties of mica and talcose slates, are called petrified wood: encrinites are called snakes: coal

plants are called rattlesnakes: favosites and certain fossil shells are called butternuts and walnuts: some varieties of ancient polyparia are regarded as the horns of deer, others as petrified pork: and even petrified squaws, pappooses, and buffaloes, have been announced as existing in the far west. It is often amusing to see with how much confidence a man, ignorant of zoology and botany, will pronounce upon these supposed cases of identicalness.

*Inference.* 7. **It appears that there have been upon the globe several distinct periods of organized existence, in which particular groups of animals and plants, exactly adapted to the varying physical condition of the globe, have been created and have successively passed away.**

*Proof.* If we take only those larger groups of animals and plants, whose almost entire distinctness from one another has been established beyond all doubt, we shall still find at least five nearly complete organic revolutions on the globe: viz. 1. The existing species. 2. Those in the tertiary strata. 3. Those in the cretaceous and oolitic systems. 4. Those in the new red sandstone group. 5. Those below the new red sandstone. Comparative Anatomy teaches us that the animals and plants in these different groups could not have lived in the same physical circumstances.

*Inference.* 8. It appears that amidst all the diversities of organic life that have existed on the globe, the same general system has always prevailed.

*Inference.* 9. It does not appear that any of the ancient forms of animal or vegetable life can be properly regarded as monstrous; or when compared with the proper standard, even heteroclitic.

*Inference.* 10. **The whole period occupied in the deposition of the fossiliferous rocks must have been immensely long.**

*Proof.* There must have been time enough for water to make depositions more than six miles in thickness, by materials worn from previous rocks, and more or less comminuted. 2. Time enough, also, to allow of hundreds of changes in the materials deposited: such changes as now require a long period for the production of one of them. 3. Time enough to allow of the growth and dissolution of animals and plants, often of microscopic littleness, sufficient to constitute almost entire mountains by their remains. 4. Time enough to produce by an extremely slow change of climate, the destruction of several nearly entire groups of organic beings. For although sudden catastrophes may have sometimes been the immediate cause of their extinction, there is reason to believe that those catastrophes did not usually happen, till such a change had taken place in the physical condition of the globe, as to render it no longer a comfortable habitation for beings of their organization. 5. We must judge of the time requisite for these deposits by similar operations now in progress; and these are in general extremely slow. The lakes of Scotland, for instance, do not shoal at the rate of more than 6 inches in a century. *Macculloch's Geology, Vol.* 1. *p.* 507. See also a full view of the arguments on this subject in *Dr. J. Pye Smith's Lectures on Scripture and Geology, p.* 391. *London Edition,* 1839.

*Objection.* 1. The rapid manner in which some deposits are formed at the present day: ex. gr. in the lake of Geneva: where within the last 800 years, the Rhone has formed a delta two miles long and 900 feet in thickness. *Lyell's Principles of Geology, Vol.* 1. *p.* 213.

*Answer.* Such examples are merely exceptions to the general law, that rivers, lakes, and the ocean are filling up with extreme slowness. Hence such cases show only that in ancient times, rocks might have been deposited over limited areas, in a rapid manner; but they do not show that such was generally the case.

*Objection.* 2. Large trunks of trees, from 20 to 60 feet long, have sometimes been found in the rocks, penetrating the strata perpendicularly, or obliquely; and standing apparently where they originally grew. Now we know that wood cannot resist decomposition for a great length

of time, and therefore, the strata around these trunks must have accumulated very rapidly; and hence the strata generally may have been rapidly formed.

*Answer.* Admitting that the strata enclosing these trunks were rapidly deposited, it might have been only such a case as is described in the first objection. But sometimes these trunks may have been drifted into a lake or pond, where a deep deposit of mud had been slowly accumulating, which remained so soft, that the heaviest part of the trunks, that is, their lower extremity, sunk to the bottom by their gravity, and thus brought the trunks into an erect position. Or suppose a forest of trees sunk by some convulsion, in the manner described by Rev. Mr. Parker in the Columbia River: how rapidly might deposits be accumulated around them, were the river a turbulent one, proceeding from a mountainous region.

*Objection.* 3. The vast accumulations that have been made of the shields of animalculæ since the commencement of the historic period, show that similar deposits of other animal remains might have been made of much greater thickness in ancient times, in a comparatively short period.

*Answer.* If it can be shown that the larger animals, like those found fossil, have a power of increase that will compare at all with the astonishing multiplication of animalculæ, the objection will be valid: but not till then: and this can never be shown.

*Objection.* 4. All the causes producing rocks may have operated in ancient times with vastly more intensity than at present.

*Answer.* This if admitted might explain the mere accumulation of materials to form rocks. But it would not account for the vast number of changes which took place in their mineral and organic character; which could have taken place without a miracle only during vast periods of time.

*Objection.* 5. The fossiliferous rocks might have been created just as we now find them, by the fiat of the Almighty, in a moment of time.

*Answer.* The possibility of such an event is admitted: but the probability is denied. If we admit that organic remains, from the unchanged elephant and rhinoceros of Siberia, to the perfectly petrified trilobites and terebratulæ of the transition strata, were never living animals, we give up the whole ground work of analogical reasoning; and the whole of physical science falls to the ground. But it is useless formally to reply to an objection, which would never be advanced by any man who had ever examined even a cabinet collection of organic remains.

*Inference* 11. It appears that every successive change, that has taken place on the earth's surface, has been an improvement of its condition.

*Proof.* Animals and plants of a higher organization have been multiplied with every change, until at last the earth was prepared for the existing races; the most generally perfect of all, with man at their head.

## Section VI.—Operation of Aqueous and Atmospheric Agencies in Producing Geological Changes.

***Prin.* The basis of nearly all correct reasoning in geology, is the analogy between the phenomena of nature in all periods of the world's history: in other words, similar effects are supposed to be the result of similar causes at all times.**

*Illustration and Proof.* This principle is founded on a belief in the constancy of nature: or that natural operations are the result of only one general system, which is regulated by invariable laws. Every other branch of physical science, equally with geology, depends upon this principle: and if it be given up, all reasoning in respect to past natural phenomena, is at an end.

## *Landslips, Icebergs, &c.*

*Descrip.* When snow and ice have long been accumulating upon the sides of steep hills, or mountains, the mere force of gravity at length, especially when the surface begins to thaw, causes vast masses to slide down the declivity, dragging along trees, soil, and loose rocks, which fill the valleys below, overwhelm whole villages, dam up and turn rivers out of their wonted channels, and produce other effects equally powerful.

*Descrip.* When these landslips occur on the steep shores of the ocean in high latitudes, the mass is precipitated into the sea, and constitutes an *iceberg.* These icebergs are drifted about by the currents in the ocean sometimes to a great distance. Those from the northern ocean are sometimes seen as far south as the 40th degree of north latitude; and those from the southern ocean, as far north as south latitude 35°. Often they are of immense size, even one or two miles in circumference; and they sensibly affect the temperature for many miles around. They have been seen to rise as much as 250 or 300 feet above the surface of the ocean; and consequently must have sunk more than 2000 feet below; as every cubic foot above, implies that there are 8 cubic feet below. In this way, large masses of sand, gravel, and bowlders, as well as animals and plants, may be transported great distances and dropped upon the bottom of the ocean, as the iceberg melts away.

## *Degradation of Rocks and Soil by Frost and Rains.*

*Descrip.* Water acts upon rocks and soils both chemically and mechanically: chemically, it dissolves some of the substances which they contain, and thus renders the mass loose and porous: mechanically, it gets between the particles and forces them asunder; so that they are more easily worn away when a current passes over them. Congelation still more effectually separates the fragments and grains, and thus renders it easy for rains and gravity to remove them to a lower level. In a single year the influence of these causes may be feeble: but as they are repeated from year to year, they become in fact some of the most powerful agencies in operation to level the surface of Continents.

## *Rivers.*

*Descrip.* Rivers produce geological changes in four modes: 1. By excavating some parts of their beds. 2. By filling up other parts. 3. By forming deposits along their banks. 4. By forming deposits, called *deltas,* at their mouths.

*Descrip.* The deposit formed in the lake of Geneva by the waters of the Rhone, has been already mentioned. Another is formed at the mouth of this river, on the shore of the Mediterranean, and is said to be mostly solid calcareous and even crystaline rock. (*Lyell's Principles of Geology, Vol.* 1. *p.* 219.) The delta of the Missisippi has advanced several leagues since New Orleans was built. The delta of the Ganges commences 220 miles from the sea, and has a base 200 miles long, and the waters of the ocean at its mouth are muddy 60 miles from the shore. Since the year 1243 the delta of the Nile has advanced a mile at Damietta; and the same at Foah since the 15th century. In 2000 years the gain of the land at the mouth of the Po, has been 18 miles, for 100 miles along the coast. The delta of the Niger extends into the interior 170 miles, and along the coast 300 miles, so as to form an area of 25.000 square miles.

*Descrip.* An immense alluvial deposit is forming at the mouth of the river Amazon and Oronoco; most of which is swept northerly by the Gulf Stream. The waters of the Amazon are not entirely mixed with those of the ocean at the distance of 300 miles from the coast. The quantity of sediment annually brought down by the Ganges, amounts to 6.386.077.440 tons; or 60 times more than the weight of the great pyramid in Egypt.

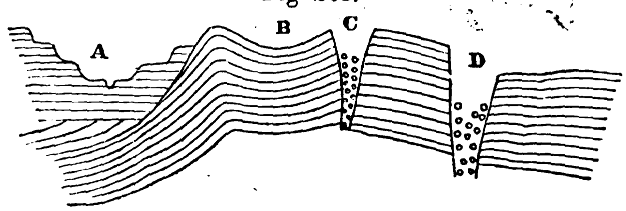
*Inf.* 1. The extensive deposits thus forming daily by rivers, need only consolidation to become

rocks of the same character as the shales, sandstones, and conglomerates of the secondary series.

*Inf.* 2. Rivers in general have not excavated their own beds; but run in valleys formed for the most part by other causes.

*Descrip. Terraced Valleys,* (of one of which a cross section is given in Fig. 265, at A,) sometimes exist in alluvial or tertiary regions, with the terraces on each side of equal height: and these appear to have been formed by the excavating operation of the rivers themselves.

Fig. 265.




*Valleys.*

*Def.* When a valley is produced by the sinking of the strata; or which is the same thing, by their elevation along two parallel anticlinal lines, it forms, what is called a *Valley of Subsidence,* as B. Fig. 265. When by the elevation of strata, they are made to separate at their highest point, a valley is produced, called a *Valley of Elevation*; as C. When a fracture has taken place in the strata, so as to leave the sides very steep and the valley narrow, a ravine is produced; as at D. In such a case the lower part of the fissure is usually filled with detritus.

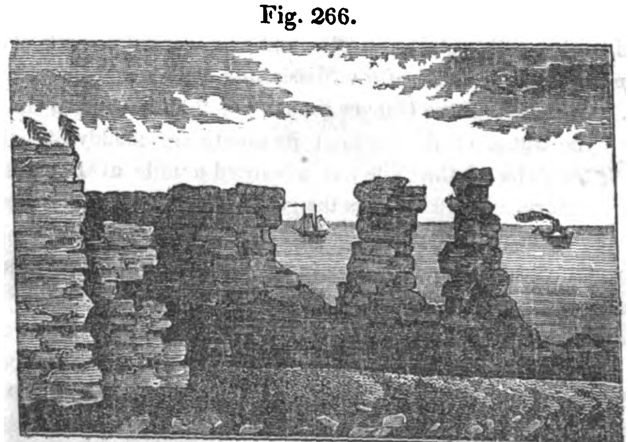
## *Agency of the Ocean.*

*Descrip.* The ocean produces geological changes in three modes. 1. By its waves: 2. By its tides: 3. By its currents. Their effect is twofold: 1. To wear away the land: 2. To accumulate detritus so as to form new land.

*Descrip.* The action of waves or breakers upon abrupt coasts, composed of rather soft materials, is very powerful in wearing them down, and preparing the detritus to be carried into the ocean by tides and currents. During storms, masses of rocks weighing from 10 to 30 tons, are torn from the ledges, and driven several rods inland, even up a surface sloping with a considerable dip towards the ocean.

Where the coast is rocky, insulated masses of rocks, (in Scotland called *Drongs,*) are left on the shore, giving a wild and picturesque effect to the scenery, as in the following sketch, Fig. 266, which was taken upon Jewell's Island in Casco Bay.

Fig. 266.



*Drongs on Jewell's Island.*

Fig. 267, is a sketch taken near the Light House on Cape Elizabeth; not far from Portland in Maine, and will give some idea of the nakedness of the coast where it is exposed to powerful storms.

Fig. 267.

## *Dunes or Downs.*

*Descrip.* The sand which is driven upon the shore by the waves, is often carried so far inland as to be beyond the reach of the returning wave; and thus an accumulation takes place, which is the origin of most of those moving sand hills, known by the name of *dunes* or *downs.* When the sand becomes dry, the sea breezes drive it farther and farther inward; the land breezes not having equal power to force it back: and at length it becomes a formidable enemy, by overwhelming fertile fields, filling up rivers, and burying villages. Sometimes these dunes occur in the interior of a country.

*Example.* Every one is familiar with the history of these dunes in Egypt. The westerly winds have brought in the sands from the Lybian desert, and all the west side of the Nile, with the exception of a few sheltered spots, has been converted into an arid waste. In Upper Egypt especially, the remains of ancient temples, palaces, cities, and villages are numerous among the drifting sands. In Europe, around the Bay of Biscay, a similar destructive process is going on. A great number of villages have been entirely destroyed; and no less than ten are now imminently threatened by sand hills, which advance at the rate of 60 or even 72 feet annually.

## *Waves and Tides.*

*Descrip.* In large inland bodies of water, such as the Mediterranean, Black and Caspian Seas, and Lake Superior, tides are scarcely perceptible; never exceeding a few inches; and in the open ocean they are very small; not exceeding 2 or 3 feet: But in narrow bays, estuaries, and friths, favorably situated for accumulating the waters, the tides rise from 10 to 40 feet; and in one instance even 60 or 70 feet on the European coasts, and in the Bay of Fundy, in Nova Scotia, 70 feet. In such cases, especially where wind and tide conspire, the effect is considerable upon limited portions of coast, both in wearing away and filing up. *De la Beche's Manual,* p. 85. *Lyell's Geology, Vol. I. p.* 238.

## *Oceanic Currents.*

*Descrip.* Oceanic currents are produced chiefly by winds. The most extensive current of this kind is the Gulf Stream. This flows out of the Indian Ocean, around the Cape of Good Hope, passes northward along the coast of Africa to the equator, thence across the Atlantic; being in-

creased by the Trade winds: and impinging against South America, it is turned northward, and continues along the coast of the United States even to the Banks of Newfoundland; from whence it turns east and southeast across the Atlantic, returning to the coast of Africa to supply the deficiency of waters there. It is estimated that this current covers a space 2000 miles in length, and 350 in breadth. Its velocity is very variable; but may be stated as from one to three and even four miles per hour; its mean rate being 1 1-2 mile. A current sets northward between America and Asia, through Berhing's Straits, which passes around the northern extremity of America, and flows out into the Atlantic in two currents, one called the Greenland current, which passes along the American Continent, at the rate sometimes of 3 or 4 miles per hour, until it meets and unites with the Gulf Stream, near the Banks of Newfoundland, where the velocity is two miles per hour: the other sets into the Atlantic between America and Europe. It is these two currents that convey icebergs as far south as the 40th degree of north latitude before they are melted. Among the Japanese Islands a current sets northeast, sometimes as strong as five miles per hour. Another sets around Cape Horn from the Pacific into the Atlantic Ocean. A constant current sets into the Mediterranean through the straits of Gibralter, at less than half a mile per hour. It has been conjectured, but not proved, that an under current sets outward through the same strait, at the bottom of the ocean. Mr. Lyell also suggests that the constant evaporation going on in that sea, may so concentrate the waters holding chloride of sodium in solution, that a deposit may now be forming at the bottom. But the deepest soundings yet made there, (5880 feet,) brought up only mud, sand, and shells. Numerous other currents of less extent exist in the ocean, which it is unnecessary to describe. They form, in fact, vast rivers in the ocean, whose velocity is usually greater than that of the larger streams upon the land. *De la Beche's Manual, p.* 91.

*Descrip.* The ordinary velocity of the great oceanic currents is from one to three miles per hour: but when they are driven through narrow straits, especially with converging shores, and the tides conspire with the current, the velocity becomes much greater, rising to 8, 10, and even in one instance to 14 miles per hour. *Lyell's Principles of Geology, Vol. I. p.* 240.

*Inf.* 1. It appears that most rivers, in some part of their course, especially when swollen by rains, possess velocity of current sufficient to remove sand and pebbles: as do also some tidal currents around particular coasts: but large rivers and most oceanic currents can only remove the finest ingredients; and as to large bowlders, it would seem that only the most violent waves and mountain streams can tear them up and roll them along.

*Inf.* 2. Oceanic currents have the power greatly to modify the situation of the materials brought to the sea by rivers and tides, and to spread them over surfaces of great extent.

*Example.* The waters of the Amazon, still retaining fine sediment, are found on the surface of the ocean 300 miles from the coast, where they are met by the Gulf stream, which runs there at the rate of 4 miles per hour. Thus are these waters carried northerly along the coast of Guiena, where an extensive deposit of mud has been formed, which extends an unknown distance into the ocean.

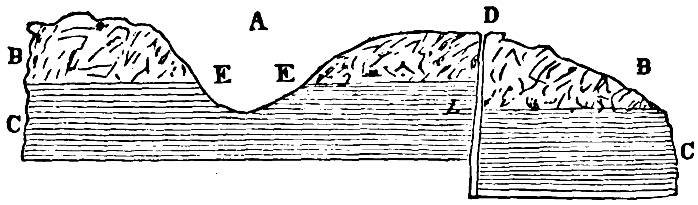
## *Phenomena of Springs.*

*Descrip.* Water is very unequally distributed among the different strata; some of them, as the argillaceous, being almost impervious to it; and others, as the arenaceous, admitting it to percolate through them with great facility. Hence when the former lie beneath the latter in a nearly horizontal position, the lower portions of the latter will become reservoirs of this fluid.

*Inference.* Hence if a valley of denudation cuts through these pervious and impervious strata, we may expect springs along their junction.

*Illus.* If B, B, Fig. 268, be the pervious and C, C, the impervious stratum, and A, the valley of denudation, we may expect springs at E, E.

Fig. 268.




*Phenomena of Springs.*

*Descrip.* If a fault occur in these strata, as at D, whereby they are sunk on the right of D, and still dip towards L, the water will be accumulated at L, because it cannot pass into C, and a spring may be expected at L.

*Descrip.* In many parts of the world, if the strata be penetrated to a considerable depth by boring, water will rise, sometimes with great force, to the surface, and continue to flow uninterruptedly. Such examples are called *Artesian Wells;* from having been first discovered at Artois, the ancient Artesium.

*Theory.* The theory of these wells is simple. In Fig. 216, suppose the formation marked as the Upper coals, and also the Millstone Grit, to be impervious to water: while the Lower coal is pervious, or the water bearing stratum. Now if excavations be made at B, or E, till the coal strata are reached, it is obvious that water will be forced to the surface by hydrostatic pressure; because some part of the water bearing stratum is higher than the points B, and E.

*Inf.* 1. If any water bearing stratum, passing under a place where boring is attempted, rises higher at any point of its prolongation than the surface where the boring is made, the water will rise above that surface: and it will fall as much below that surface as is the level of the highest part of the pervious stratum.

*Inf.* 2. Hence borings of this sort may fail; first, because no water bearing stratum is reached; and secondly, because that stratum does not rise high enough above the place to bring the water to the surface.

*Inf.* 3. These explorations have proved that subterranean streams of water exist: some of which have a communication with water at the surface.

*Depths of the borings.* In England, Artesian well have been carried to the depth of 620 feet with success. In France they have been sunk 800 and even 1200 feet, and in one instance near Paris to 1666 feet: and in the two last cases without success. In the United States, borings for salt water in the Western States, have been carried as deep as 800 or 900 feet.

*Remark.* Until recently these borings have been generally performed by means of a continuous iron rod, sharpened like a drill at the lower end. But a far more convenient and economical method, which has long been in use in China, has lately been adopted: viz. to use a heavy cylinder of iron in the same manner, by means of a rope attached to its upper end; a bore with valves being connected with the lower end, for bringing up the comminuted materials. *Buckland's Bridgewater Treatise, Vol. I. p* 568.

## *Salt Springs.*

*Descrip.* The most important mineral springs in an economical point of view, are those which produce common salt. These are called salines, or rather such is the name of the region through which the springs issue. They occur in various parts of the world; and the water is extensively evaporated to obtain table salt. They contain also other salts; nearly the same in fact, as the ocean.

*Examples.* Some of these springs contain less, but usually they contain more salt, than the waters of the ocean. Some of the Cheshire springs in England yield 25 per cent.: whereas sea

water rarely contains more than 4 per cent. In the United States they contain from 10 to 20 per cent. They are used in New York, Ohio, Virginia, Pennsylvania, Illinois, Michigan, Missouri, Arkansas, and Upper Canada. 450 gallons of water at Boon's Lick in Missouri, yield a bushel of salt: 300 gallons at Conemaugh, Penn.: 280, at Shawneetown, Ill.: 120, at St. Catherine's U. C.: 75, at Kenawha, Vir.: 80, at Grand river, Arkan.: 50, at Muskingum, Ohio: and 48 to 45, at Onondaga, N. Y.: 350 gallons of sea water, yield a bushel at Nantucket. In 1829, according to a report of the Secretary of the Treasury, 3,804,229 bushels of salt were made in the United States. Since that time the quantity has greatly increased. In 1835, no less than 2,222,694 bushels were made at the Onondago Springs in N. Y. alone; and 3,000,000 bushels at the Kenhawa Springs in Virginia. In all these places deep borings are necessary, sometimes even as deep as 1000 feet: but usually the brine becomes stronger the deeper the excavation.

## *Aqueous Agency between the Tertiary and Alluvial Epochs:—often called Diluvial Action.*

### 1. *Dispersion of Diluvium.*

*Descrip.* Diluvial are distinguished from tertiary deposits by two circumstances. 1. The tertiary strata were deposited in limited troughs and basins; whereas diluvium is found in every part of the northern portions of the globe, and at all altitudes, with a few exceptions; and therefore resulted from some cause very general in its influence. 2. The tertiary strata were deposited in waters comparatively quiet: whereas diluvium has been the result of powerful currents. Towards the close of the diluvial epoch, however, when the waters became more tranquil, the deposits are with more difficulty distinguished from the tertiary strata except by their position above the coarser diluvium.

*Descrip.* Diluvial are distinguished from alluvial deposits; 1. By the occurrence of the former in situations where no existing alluvial agency could have produced them. 2. By the marks of greater violence in the movements of the waters that produced the former, than in any waters which now produce the latter. But in some situations, where we cannot apply these two marks, the two deposits are with difficulty distinguished.

*Descrip.* The dispersion of diluvium appears, so far as the facts are yet known, to have been the result of two causes—perhaps, however, not of a different nature, but operating in one case on a limited, and in the other on a more general scale. The first cause of this dispersion is the elevation of particular mountain chains; whereby the diluvium has been scattered from the axis of the mountain outwards.

*Prin.* The second cause of diluvial action, whatever it may have been, appears to have operated on a more extended scale: and to have drifted the diluvium southward over nearly all the northern hemisphere.

*Proof.* To begin with the American continent, at the most easterly point where observations to be depended upon have been made: we find that the bowlders spread over the southern part of Nova Scotia were derived, according to Sir Alexander Coke and Messrs. Jackson and Alger, from the ledges in the northern part of the province. Through the whole extent of Maine, the evidence is very striking of the southerly drift of the diluvium, the course being usually a few degrees east of south. And transported bowlders are even found on the summit of Mt. Ktaadn, which is 5,300 feet high. *Dr. Jackson's First and Second Reports on the Geology of Maine,* 1837 *and* 1838. *Also his Reports on the Public Lands of Maine and Mass. p.* 16, *Second Report.*

*Descrip.* In the Third Part of my Report, I have given abundant details respecting the dispersion of Diluvium in Massachusetts. On Long Island the diluvium corresponds to the rocks on the continent: those of different kinds always lying south of the ledges from which they were derived. (*Prof. Mather's first annual Report on the first Geological District of New York, p.* 88.

1837.) In the eastern part of N. York, the current was southeasterly; as in the western part of Massachusetts: But towards the western parts of the State, its general course appears sometimes to have been west of south. (*Mr. Hall's second annual Report on the Fourth Geological District of New York, p.* 308.) In the southeasterly part of the state, bordering on Pennsylvania and New Jersy, its direction varied from south several degrees west, to southeast: and near the city of N. York, the course was N. W. and S. E. (*Amer. Jour. Science, Vol.* 23. *p.* 243. *And Vol.* 16, *p.* 357. *Also Prof. Gale's Report for* 1839, *upon the Geology of the First District.*) In the fossiliferous region of western N. York, and in the states south of the great western lakes, great numbers of bowlders of primitive rocks are strewed over the surface, significantly called *lost rocks*. These have been satisfactorily traced to the beds from which they are derived on the north side of the lakes in Upper Canada. (*See the papers of the Messrs. Lapham, in Vol.* 22, *and of Dr. Hildreth, in Vol.* 29 *of Amer. Jour. Science. Also the Geological Reports on the states of Ohio and Michigan.*) Similar evidence of the southeasterly drift of diluvium exists in Virginia. (*Prof. W. B. Roger's Report on the Geological Reconnoisance of the State of Virginia, p.* 16.) According to Dr. Drake, primitive pebbles occur on the right bank of the Mississippi, as far south as Natchez. *Amer. Jour. Science, Vol.* 29. *p.* 209.

*Descrip.* According to Mr. Catlin, (*Amer. Jour. Science, Vol.* 38. *p.* 143.) vast quantities of bowlders of primary rocks "are strewed over the great valley of the Missouri and Mississippi, from the Yellow Stone almost to the Gulf of Mexico," which have been drifted thither from the northwest.

*Descrip.* The distance to which bowlders have been driven southeasterly from their native beds in our country, has not been very satisfactorily determined. In New England they have been traced rarely more than 100 to 200 miles: But in the western States they are strewed over a greater distance. I am informed by the gentlemen engaged in the geological surveys of those states, that primary bowlders are rarely found south of the river Ohio; but they are strewed over almost every part of Ohio and Michagan. Now the primary rocks from which they have been derived, are found between 400 and 500 miles to the north of that river.

*Descrip.* On the eastern continent the evidences of a southerly diluvial current seems almost equally strong. In Great Britian the general course was a little east of south, modified, however, and sometimes very much changed, by the shape of the mountains; some of which, as the Penine chain, appear not to have been passed over by the bowlders, except at their lowest points. In the east part of England, the diluvium appears to have been derived from Scotland, and perhaps also from Norway. (*De la Beche's Mauual, p.* 189. *Phillips' Geology, p.* 208. *Also his Treatise on Geology, Vol.* 1. *p.* 274.) On the continent of Europe, the Netherlands, Denmark, the plains of the north of Germany, of Poland, and Russia, are strewed over with bowlders and pebbles, which can be traced to the parent rocks in Sweden and Finland; in which countries they are yet more numerous upon the surface. In most cases these bowlders must have crossed the Baltic. In Sweden the current appears to have set S. S. W. The blocks decrease in size on going south, and finally at a great distance (more than 400 miles, *Greenough's Geology, p* 138.) they disappear. *Tableau des Terrains par Al. Brongniart, p.* 77. *Traite Elementaire de Geologie par M. Rozet, Tome* 1. *p.* 270. *De la Beche's Manual, p.* 189.

*Descrip.* According to Mr. Darwin, the equatorial regions of South America, exhibit but few marks of diluvial action, or rather they are destitute of bowlders. But beyond the 41° South latitude, they appear in Chili and Patagonia. Hence some geologists, (Lyell and Darwin, see *Lyell's Elements, p.* 137.) infer that diluvial phenomena are limited to the colder regions of the globe. But De la Beche describes diluvial detritus as abundant in Jamaica in the West Indies; especially on the plain around Kingston; and he says that it appears to have been drifted from the north. (*Geological Trans. Second Series, Vol.* 7. *p.* 182.) A similar statement was made to me by the late Prof. Hovey, who resided two years in the West Indies. Prof. Struder states that

in the hill country at the foot of the Himalayah mountains in India, erratic bowlders occur. (*Amer. Jour. Science*, *Vol.* 36 *p.* 330.) Probably, therefore, the equatorial regions have not yet been examined extensively enough to settle this point.

## 2. *Effects of Diluvial Action upon the Earth's Surface.*

*Descrip.* The tops and steep sides of high mountains and alluvial plains are nearly all the parts of the northern hemisphere not covered with a coat of bowlders, gravel, and sand ; whose thickness varies from a few inches to 100 or 200 feet. Scarcely any mountains, indeed, except the Pyrenees, the Appenines, the Carpathians and the mountains of Bohemia (*Traite de Geologie par M. Rozet*, *p.* 272, *Tome* 1.) are wanting in diluvium ; and sometimes very large blocks are poised upon their summits.

*Descrip.* The most abundant accumulations of diluvial detritus are found upon moderately elevated ground, near the bases of mountains, and especially near gorges and defiles.

*Descrip.* The large bowlders are usually diffused through every part of the finer detritus ; but as alluvial agencies wear away the latter, they often leave the former insulated ; and when they are numerous, they give a picturesque appearance to the landscape.

*Descrip.* Diluvial action appears to have destroyed numerous species of animals that inhabited the northern regions of the globe at the time of its occurrence.

*Proof.* In diluvial accumulations in the northern hemisphere, have been found the bones of several species of mastodon, hippopotamus, rhinoceros, and bear, as well as the mammoth or elephant, megatherium, megalonyx, hyæna, deer, dinotherium, horse, ox, &c.: animals, of whose existence since that event we have no evidence. Not less than 100 species have already been found in diluvium, although not more than half are extinct.

*Inference.* A sudden fall of temperature took place in the northern hemisphere at the period of diluvial action.

*Proof.* The animals whose remains are found in diluvium are mostly such as live in tropical climates ; which shows that a higher temperature than now exists in these countries, prevailed at the commencement of the diluvial action. And that the change was sudden, appears from the occurrence of the elephant and rhinoceros undecayed in the frozen mud of Siberia, for they must have been encased suddenly in ice to prevent their putrefaction.

*Descrip.* One of the most remarkable effects of diluvial action, is the smoothing and furrowing of the surfaces of rocks in place.

*Examples.* In the state of Maine is a good deal of slaty rock, often standing upon its edges, that admirably resists atmospheric agencies : and hence it presents a multitude of examples of well marked diluvial furrows. Around the city of Portland, they are very abundant and very distinct ; having a direction N. 10° to 15° W. and S 10° to 15° E Farther east, as at Hope and Appleton, they run nearly N. W. and S. E. and some of them are a foot in depth, and six inches wide. (*First Report on the Geology of Maine*, *p.* 57.) In other parts of the state, the direction is nearly north and south, or even inclining a few degrees to the N. E and S. W. (*Second Report on the Geology of Maine*, *p.* 91.) A full account of these furrows in Massachusetts, has been given on page 386.

Near the city of New York, according to Prof. Gale, they run nearly N. W. and S. E. In the Western part of N. York, they are numerous, and they run sometimes S. S. W. and N. N. E. They are common also, upon the mountains of Pennsylvania ; and also in Ohio, Michigan and Illinois where their most usual course is from N. W. to S. E.

*Descrip.* On the eastern continent these diluvial furrows appear to be far less common than in this country : for notwithstanding the great ability and zeal displayed by European geologists, only a few cases of such grooves have yet been recorded. In Scotland however, they were no-

ticed long ago by Sir. James Hall, on greenstone and other rocks, having a direction N. W. and S. E: also a similar case is mentioned in North Wales, and in the Brora coal region in Scotland, where they run N. N. W. and S. S. E. They occur also in the Alps, and in Scandinavia this phenomenon seems nearly as common as in New England. Their general course is N. N. E. and S. S. W. though there are local deviations, occasioned by the forms of the hills. "Monsieur Sefstroom," says the distinguished Berzelius, "has found that the northeast part of the mountains of Sweden, are, throughout, rounded and worn from the base to the summit, so as to resemble at a distance, sacks of wool, piled upon each other. The southwest sides of these mountains present almost fresh fractures of the rocks, with their angles rounded little or none."

## *Theories of Diluvial Action.*

*Rem.* Although the theories of diluvial action have not been considered as fully in the Third Part of my Report as would be desirable, yet I am compelled, for want of room, to refer the reader to that place.

## SECTION VII.—OPERATION OF ORGANIC AGENCIES IN PRODUCING GEOLOGICAL CHANGES.

*Remark.* Many of the facts naturally belonging to this Section, have been necessarily anticipated in the preceding Sections; and will therefore need only to be referred to in this place.

## *Agency of Man.*

*Prin.* The human race produce geological changes in several modes: 1. By the destruction of vast numbers of animals and plants to make room for themselves. 2. By aiding in the wide distribution of many animals and plants, that accompany man in his migrations. 3. By destroying the equilibrium between conflicting species of animals and plants; and thus enabling some species to predominate at the expense of others. 4. By altering the climate of large countries by means of cultivation. 5. By resisting the encroachments of rivers and the ocean. 6. By helping to degrade the higher parts of the earth's surface. 7. By contributing peculiar fossil relics to the alluvial depositions now going on, on the land and in the sea: such as the skeletons of his own frame, the various productions of his art, numerous gold and silver coins, jewelry, cannon balls, &c. that sink to the bottom of the ocean in shipwrecks, or become otherwise entombed.

*Inference.* Some writers maintain that as species of animals and plants disappear from the earth, new species are created to take their place, that the proper equilibrium of organic nature may be preserved. But as no certain example of the creation of a new species in such circumstances has yet been discovered, this opinion can be regarded only as an hypothesis: And the majority of authors suppose that in general, no new creation takes place, until nearly the entire race, inhabiting a country at any one period, have been destroyed; either by a sudden catastrophe, or in the slow manner that has been described.

## *Agency of Other Animals.*

*Prin.* Very many other animals exert an influence on geological changes analogous to that of man, though less in degree, except the following.

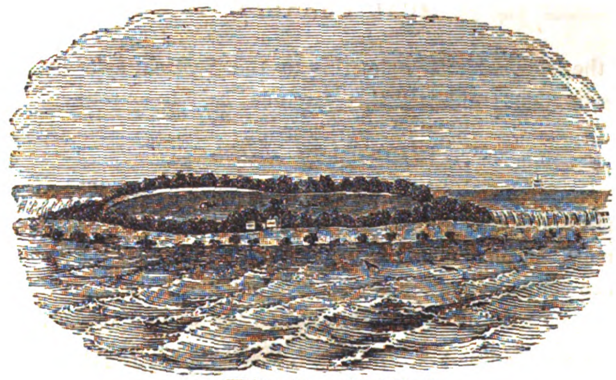
## *Polyparia or Polyps.*

*Descrip.* Coral reefs are ridges of calcareous rock, whose basis is coral, (chiefly of the general Porites, Astreæ, Madrepora, Meandrina and Caryophillia,) and whose interstices and surface are covered by broken fragments of the same, with broken shells and echini, and sand, all cemented together by calcareous matter. They are built up by the Polyparia, apparently on the margin of

volcanic craters, beneath the ocean, not generally from a depth greater than 25 or 30 feet, yet sometimes probably 90 feet. The polyparia continue to build until the ridge gets to the surface of the sea at low water; after which, the sea washes upon it fragments of coral, drift wood, &c. and a soil gradually accumulates, which is at length occupied by animals with man at their head. The reefs are usually arranged in a circular manner, with a lagoon in the center, where, in water a few fathoms deep, grow an abundance of delicate species of corals, and oth r marine animals, whose beautiful forms and colors rival the richest flower garden. Volcanic agency often lifts the reef far above the waters, and sometimes covers one reef with lava, which in its turn is covered with another formation of coral. The growth of coral structures is so extremely slow, that centuries are required to produce any important progress. The rate of increase has not been determined.

*Descrip.* The diameter of these circular reefs has been found to vary from less than one to 30 miles. On the outside, the reef is usually very precipitous, and the water often of unfathomable depth. Fig. 269, is a view of one of these circular islands in the south seas, called Whitsunday Isle; so far reclaimed from the waters as to be covered with cocoa nut trees and with some human dwellings.

Fig. 269.



*Whitsunday: a Coral Island.*

*Descrip.* These circular islets occur abundantly in the Pacific Ocean, between the thirtieth parallels of latitude. They abound also, in the Indian Ocean, in the Arabian and Persian Gulfs, in the West Indies, &c. Usually they are scattered in a linear manner over a great extent. Thus, on the eastern coast of New Holland, is a reef 350 miles long. Disappointment Islands and Duff's Group are connected by 600 miles of coral reefs, over which the natives can travel from one island to another. Between New Holland and New Guinea, is a line of reefs 700 miles long, interrupted in no place by channels more than 30 miles wide. A chain of coral islets 480 geographical miles long, has long been known by the name of the Maldivas. *Lyell's Principles of Geology, Vol. 2. p. 172.*

## *Agency of Plants.*

*Descrip.* Animal and vegetable substances, when buried in the earth, or the waters, sometimes undergo an almost entire decomposition: at other times, this is very partial; and sometimes the change is so slow that for years scarcely no apparent progress is made. Different substances will be the result of these different degrees of decomposition.

## *Drift Wood.*

*Descrip.* Large rivers which pass through vast forests, carry down immense quantities of timber. When these rivers overflow their banks, this timber is in part deposited upon the low

grounds. But much of it also collects in the eddies along the shores, or is carried into the ocean. After a time it becomes *water-logged*; that is, saturated with water; and sinks to the bottom. Thus a deposit of entangled wood is often formed over large areas. This is subsequently covered by mud; and then another layer of wood is brought over the mud: so that in the course of ages, several alternations of wood and soil are accumulated.

*Example* 1. The Mississippi furnishes the most remarkable example known of these accumulations. In consequence of some obstruction in the arm of the river called the Atchafalaya, supposed to have been formerly the bed of the Red River, a raft had accumulated in 35 years, which in 1816 was 10 miles long, 220 yards wide, and 8 feet thick. Although floating, it was covered with living plants, and of course with soil. Similar rafts occur on the Red River: and one on the Washita, concealed the surface for 17 leagues. At the mouth of the Mississippi, also, numerous alternations of drift wood and mud exist, extending over hundreds of square leagues. *Lyell's Principles of Geology, vol.* 1. *p.* 182, 228. *Am. Journal of Science, vol.* 3. *p.* 17.

*Inference.* In the history of common peat and drift wood, we see the origin of the beds of coal which exist in the older strata: For it needs only that the layers of peat (in which term I include submerged drift wood,) should be bituminized, and the intervening layers of sand and mud be consolidated, in order to produce a genuine coal formation. Common marsh peat alone, can have originated but a small part of the beds of coal. *Phillip's Geology, p.* 116.

## *Consolidation of Loose Materials.*

*Prin.* Carbonate of lime, conveyed in a state of solution among the loose particles of gravel, sand, clay, or mud, and there precipitated, becomes a very efficient agent of consolidation.

*Examples.* 1. On the shores of the Bermuda and West Indian Islands, extensive accumulations of broken shells, corals, and sand, are formed upon the shores by the waves: and these are subsequently consolidated, frequently into very hard rock, by the infiltration of the water which contains carbonate of lime in solution. The famous Gaudalope rock, in which human skeletons, along with pottery, stone arrow heads, and wooden ornaments, are found, is of the same kind. 2. The Mediterranean delta of the Rhone, is ascertained to be in a good measure solid rock, produced by the numerous springs that empty into it, that contain carbonate of lime in solution. The same is true of the deposits at the mouths of other rivers in the south part of Italy: but more especially on the east coast of the Mediteranean; where the ancient Sidon, formerly on the coast, is now two miles inland. *Lyell's Principles of Geology, vol I. p.* 286.

*Prin.* Another agent of consolidation is the red or peroxide of iron; or rather the carbonate of iron; since the peroxide is not soluble in water, without carbonic acid.

*Prin.* Silica dissolved in water, appears to have been in former times, an important agent in consolidating rocks: But at the present day it seems to be limited chiefly to deposits from thermal waters; since it is only water in this condition that will dissolve silica in much quantity.

*Prin.* Heat is an important agent in the consolidation of rocks: the most so, when it produces complete fusion: yet this is not necessary to the production of a good degree of solidification.

*Prin.* In many of the cases that have been described, great pressure assists in the work of consolidation. Indeed, it is sometimes sufficient of itself to bring the particles within the sphere of cohesive attraction.

## *General Inference from this and the Preceeding Section.*

*Inf.* From the facts detailed in this and the preceding Section, it appears that all the stratified fossiliferous rocks of any importance, may have resulted from causes now in operation.

*Proof and Examples.* 1. Beds of clay need only to be consolidated to become clay slate, graywacke slate, or shale. 2. The same is true of fine mud. 3. Sand consolidated by carbonate of lime, will produce calcareous sandstone: by iron, ferruginous sandstone. 4. Diluvial deposits,

in like manner, will form conglomerates of every age, according to variations in the agents of consolidation. 5. Marls need only to be consolidated to form argillaceous limestones; and if sand be mixed with marl, the limestone will be siliceous. 6. Coral reefs and deposits of Travertin, subjected to strong heat under pressure, will produce those secondary limestones that are more or less crystaline: but more of this under the next Section. 7. We have already seen how beds of lignite and coal may be produced from peat, and drift wood 8. The formation of such extensive beds of rock salt and gypsum, as occur in the secondary and tertiary rocks, is more difficult to explain by any cause now in operation. And yet in respect to the former, it is said that the lake of Indersk, 20 leagues in circumference, on the Steppes of Siberia, has a crust of salt on its bottom more than six inches thick, hard as stone, and perfectly white. The lake of Penon Blanco in Mexico, yearly dries up, and leaves a deposit of salt, sufficient to supply the country. (*Ure's Geology*, p. 373.) But the formation of rock salt is usually connected with ancient volcanic action

## SECTION VIII.—OPERATION OF IGNEOUS AGENCIES IN PRODUCING GEOLOGICAL CHANGES.

*Prin.* Volcanic agency has been at work from the earliest periods of the world's history; producing all the forms and phenomena of the unstratified rocks, from granite to the most recent lava. Modern volcanos will first come under consideration.

*Def.* These are of two kinds, Extinct and Active. The former have not been in operation within the historic period: the latter are constantly or intermittingly in action.

*Def.* When nothing but aqueous and corrosive vapors have been emitted from a volcanic elevation for centuries, such elevation is called a *Solfatara, or Fumerole.*

*Descrip.* As a general fact, volcanic vents are not insulated mountains, but are arranged in extensive lines, or zones; often reaching half around the globe.

*Examples.* 1. Perhaps the most remarkable line of vents is the long chain of islands commencing with Alaska on the coasts of Russian America, embracing the Aleutian Islands, Kamschatka, the Kurilian, Japanese, Phillipine, and Moluccan Isles, and then turning, it includes Sumbawa, Java, and Sumatra, and terminates at Barren Island in the Bay of Bengal. 2. Another almost equally extensive line, commences at the southern extremity of S America, and following the chain of the Andes, passes along the Cordilleras of Mexico, thence into California, and thence northward as far at least as Columbia River; which it crosses between the Pacific Ocean and the Rocky Mountains. (*Parker's Tour beyond the Rocky Mountains.*) 3. A belt 10 degrees of latitude in breadth, and 1000 miles long, extending from the Azore Islands to the Caspian Sea, abounds in volcanos; though very much scattered. The region around the Mediterranean, is perhaps better known for volcanic agency than any other on the globe; because no eruption occurs there unnoticed.

*Def.* Volcanos not arranged in lines or zones, are called central volcanos, and are more or less insulated.

*Examples.* Iceland, the Sandwich Islands, Society Islands, Island of Bourborn, Jorullo in Mexico, &c. a region in Central Asia, of 2500 square geographical miles, from 800 to 1200 miles from the ocean. *De la Beche's Theoretical Geology*, p. 130.

The following Table will show how the Active Volcanos and Solfataras are distributed on the Globe.

| | On Continents. | On Islands. | Total. |
|---|---|---|---|
| Europe, | 4 | 20 | 24 |
| Africa, | 2 | 9 | 11 |
| Asia, | 17 | 29 | 46 |
| America, | 86 | 28 | 114 |
| Oceanica, | | 108 | 108 |
| Total. | 109 | 194 | 303 |

*Descrip.* 194 of these volcanos, or about two thirds, are situated upon the islands of the sea; and of the remaining third, the greater part are situated upon the borders of the sea, or a little distance from the coast. *Girardin's Considerations Generales sur les Volcans, p.* 25.

*Inference.* Hence it is inferred that water acts an important part in volcanic phenomena: indeed, it seems generally admitted that the immediate cause of an eruption is the expansive force of steam and liberated gases. It ought not to be forgotten, however, that some volcanos are far inland: as Jorullo in Mexico, and the volcanos in central Asia.

## *Intermittent Volcanos.*

*Descrip.* Only a few volcanos are constantly active: in most cases their operation is paroxysmal; and is succeeded by longer or shorter intervals of repose. This interval varies from a few months to seventeen centuries. In the Island of Ischia, the latter period has been known to intervene between two eruptions.

## *Phenomena of an Eruption.*

*Descrip.* Probably the most remarkable eruption of modern times took place in 1815, in the island of Sumbawa, one of the Molucca group. It commenced on the 5th of April, and did not entirely cease until July. The explosions were heard in Sumatra, 970 geographical miles distant in one direction, and at Ternate in the opposite direction, 720 miles distant. So heavy was the fall of ashes at the distance of 40 miles, that houses were crushed and destroyed beneath them. Towards Celebes, they were carried to the distance of 217 miles; and towards Java, 300 miles, so as to occasion a darkness greater than that of the darkest night. On the 12th of April, the floating cinders to the westward of Sumatra, were two feet thick: and ships were forced through them with difficulty. Large tracts of country were covered by the lava: and out of 12.000 inhabitants on the island, only 26 survived.

*Descrip.* Sometimes during a violent eruption, the whole mountain, or cone, is either blown to pieces, or falls into the gulph beneath, and its place is afterwards occupied as a lake.

## *Dynamics of Volcanic Agency.*

*Descrip.* Taking the specific gravity of lava at 2 8, the following Table will show the force requisite to cause it to flow over the tops of the several volcanos, whose names are given, with their height above the sea. The initial velocity which such a force would produce, is also given in the last column.

| Name | Height in feet. | Force exerted upon the lava. | Initial velocity per second. |
|---|---|---|---|
| Stromboli, (highest peak,) | 2168 | 176 Atmospheres. | 371 feet. |
| Vesuvius, | 3874 | 314 | 496 |
| Jorullo, Mexico, | 3942 | 319 | 502 |
| Hecla, Iceland, | 5106 | 413 | 570 |
| Etna, | 10892 | 882 | 832 |
| Teneriffe, | 12464 | 1009 | 896 |

| *Name.* | *Height.* | *Force.* | *Initial Velocity.* |
|---|---|---|---|
| Mouna Kea, Sandwich Islands, | 14700 | 1191 | 966 |
| Popocatapetl, Mexico, | 17712 | 1435 | 1062 |
| Mount Elius, | 18079 | 1465 | 1072 |
| Cotopaxi, Quito, | 18869 | 1492 | 1104 |

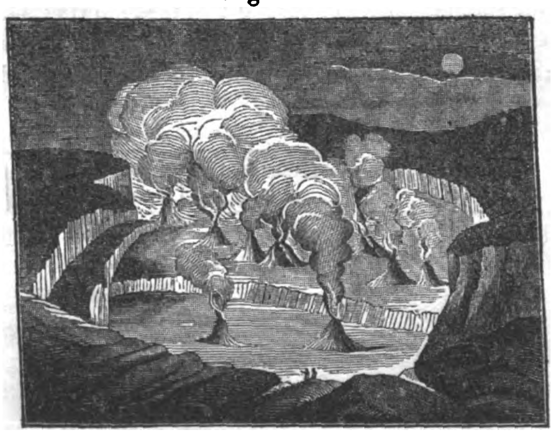
*Descrip.* The amount of melted matter ejected from Vesuvius in the eruption of 1737, was estimated at 11.839.168 cubic yards: and in that in 1794, at 22.435.520 cubic yards. But these quantities are small compared with those which Etna has sometimes disgorged. In 1669, the amount of lava was 20 times greater than the whole mass of the mountain; and in 1660, when 77.000 persons were destroyed, the lava covered 84 square miles. Yet the greatest eruption of modern times was from Skaptar Jokul in Iceland, in 1783. Two streams of lava flowed in opposite directions; one of them 50 miles long and 12 broad; and the other 40 miles long and 7 broad: both having an average thickness of 100 feet: which was sometimes increased to 500 or 600 feet. Twenty villages and 9000 inhabitants were destroyed. *Lyell's Prin. of Geology, Vol.* 1. *p.* 343.

## *Volcanos constantly Active.*

*Descrip.* A few volcanic vents have been constantly active since they were first discovered. They always contain lava in a state of ebulition; and vapors and gasses are constantly escaping.

*Ex.* The most remarkable volcano on the globe is that of Kirauea in the Sandwich Islands, on Hawaii; for the first accurate account of which we are indebted to American Missionaries. (*American Jour. of Science, Vol.* 11, *p.* 1, and 362.) Rev. Messrs. Stewart and Ellis, the first an American, and the latter an English Missionary, have both given us most graphic and thrilling descriptions of it. It appears to be situated upon a plain 8000, or 10.000 feet above the ocean; and at the foot of Mouna Roa. In approaching the crater, it is necessary to descend two terraces, each from 100 to 200 feet high, and extending entirely around the volcano. The outer one is 20 and the inner one 15 miles in circumference; and they obviously form the margin of vast craters, formerly existing. Arrived at the margin of the present crater, the observer has before him a crescent shaped gulf, 1500 feet deep; at whose bottom, which is from 5 to 7 miles in circumference, the top being from 8 to 10, is a vast lake of lava, in some parts molten, in others covered with a crust; while in numerous places (some have noticed as many as 50 at once,) are small cones, with smoke and lava issuing out of them from time to time. Sometimes, and especially at night, such masses of lava are forced up, that a lake of liquid fire, not less than two miles in circumference, is seen dashing up its angry billows, and forming one of the grandest and most thrilling objects that the imagination can conceive. Fig. 270, is a view of this volcano taken by Mr. Ellis.

Fig. 270.



*Volcano of Kirauea: Sandwich Islands.*

## Earthquakes.

*Descrip.* Earthquakes almost always precede a volcanic eruption; and cease when the lava gets vent.

*Inference.* 1. Hence the proximate cause of earthquakes is obvious: viz. the expansive efforts of volcanic matter, confined beneath the earth's surface.

*Inference.* 2. Hence too the ultimate cause of volcanos and earthquakes, is the same; whatever that cause may be.

*Example.* The cases that might be mentioned, of cities, and towns, wholly or in part submerged by the ocean, in consequence of earthquakes, are very numerous. In the year 876, Mount Acraces is said to have fallen into the sea: in 541, Pompeiopolis was half swallowed up: in 1692, a part of Port Royal in the West Indies was sunk: in 1755, a part of Lisbon: in 1812, a part of Caraccas. About the same time numerous earthquakes agitated the valley of the Mississippi, for an extent of 300 miles, from the mouth of the Ohio, to that of St. Francis; whereby numerous tracts were sunk down and others raised, lakes and islands were formed, and the bed of the Mississippi was exceedingly altered. In 1819, the bed of the Indus at its mouth, was sunk 18 feet, and the village and port of Sindree submerged. At the same time a tract of the delta of the Indus, 50 miles long and 16 broad, was elevated about 10 feet. In Caraccas, in 1790, a forest was sunk over a space of 800 yards in diameter, to the depth of 80 or 100 yards. In 1783, a large part of Calabria was terribly convulsed by earthquakes, over an area of 500 square miles. The shocks lasted for four years: in 1783, there were 949, and in 1784, 151. A vast number of fissures of every form were made in the earth, and of course a great many local elevations and subsidences; which however do not appear to have exceeded a few feet. In some sandy plains, singular circular hollows a few feet in diameter, and in the form of an inverted cone, were produced by the water, which was forced up through the soil. Some of these are exhibited on Fig. 271.

Fig. 271.

*Holes formed by an Earthquake.*

## Vertical Movements of Land without Earthquakes.

*Descrip.* It seems to be pretty well established, that various parts of our present continents are subject to vertical movements, either of elevation or depression, or of both, in alternation; and that too in districts not known to be subject to the action of earthquakes, or of volcanic agency in any form.

*Example.* The most certain example of elevation of an extensive tract of country in comparatively recent times, is that of the northern shores of the Baltic, investigated with great ability by Von Buch and Lyell. Some parts of the coast appear to have experienced no vertical movement. But from Gothenbergh to Torneo, and from thence to North Cape, a distance of more than 1000 geographical miles, the country appears to have been raised up from 100 to 200 feet above the sea. The breadth of the region thus elevated is not known, and the rate at which the land rises (in some places towards 4 feet in a century) is different, in different places. The evidence that such a movement is taking place, is principally derived from the shells of mollusca now living in the Baltic, being found at the elevations above named; and some of the barnacles attached to the rocks. They have been discovered inland in one instance 70 miles. (*Lyell's. Principles of Geology, Vol.* 1. *p.* 437.

## *Extinct Volcanos.*

*Descrip.* The extinct volcanos are of very different ages. Some of them were active during the tertiary period, some during the diluvial epoch; and some since that period. The lava, especially in the most ancient, was not always ejected from conical elevations, so as to form regular craters, but along extended fissures. In some instances, as in a mountain called the Puy de Chopine in Auvergne, which stands in an ancient crater, and rises 2000 feet above an elevated granitic plain, itself about 2800 feet above the sea, there is a mixture of trachyte and unaltered granite.

*Examples.* The extinct volcanos of Auvergne, and the south of France have long excited deep interest; and have been fully illustrated by Scrope, Bakewell, and others. Near Clermont, the landscape has as decidedly a volcanic aspect as in any part of the world; of which Fig. 272, will convey some idea.

Fig. 272.

*Extinct Volcano: Auvergne.*

2. Extinct volcanos exist also in Spain, in Portugal, in Germany, along the Rhine, in Hungary, Transylvania, in Styria, and in the vicinity of the Dead Sea in Palestine.

3. According to Professor Parrot, Mount Arrarat in Asia, is an extinct volcano. A specimen sent me by Rev. Justin Perkins from that mountain is decidedly vesicular lava.

4. A large proportion of the lofty peaks of the Andes and the mountains of Mexico belong to the class of extinct volcanos: and it is very probable, from the statements of Rev. Mr. Parker and others, that a vast region between the Rocky Mountains and the Pacific Ocean is of the same character.

## *The Older Unstratified Rocks.*

*Prin.* The different unstratified rocks appear to be the result of volcanic agency exerted at different periods under different circumstances.

*Proof.* 1. *Identity of lithological characters between recent lavas and several varieties of unstratified rocks.* The amygdaloids of the trap rocks often exactly resemble those vesicular lavas which are cooled in the open air: while the compact trap rocks can scarcely be distinguished from the compact lavas of submarine production. Some varieties of trachyte very much resemble granite; and the two rocks often pass insensibly into each other; so that it is difficult to say whether trachyte be melted granite, or a portion of the materials out of which granite was originally produced, cooled in a different manner.

*Proof.* 2. *The insensible gradation of the different unstratified rocks into one another.*

*Proof.* 3. *The mode of occurrence of the unstratified in relation to the stratified rocks.* We have seen, (Section IV.) that the former exist as protruding, intruding, and overlying masses, and occupying veins in the latter. Now these are the precise modes in which recent lava occurs when connected with stratified rocks: whereas no example can be produced in which rocks have been made to take these forms by aqueous agency. Indeed, it is difficult to conceive how this would be possible.

*Proof.* 4. *The columnar structure of the trap rocks.* This structure is not uncommon in lavas. The experiment of Mr. Watts also, upon 700 pounds of melted basalt, which on cooling assumed the columnar form, as detailed in Section IV, confirms this view: whereas no example of such a structure from aqueous agency has ever been found.

*Proof.* 5. *The crystaline structure of some of the unstratified rocks.* When several substances are contained in an aqueous menstruum, it is difficult to make them crystalize except in succession; whereas in granite the different ingredients appear to have crystalised simultaneously. And if the materials of granite, or of glass, be melted and slowly cooled, especially under pressure, most if not all the ingredients will assume more or less of a crystaline form at the same time.

*Proof.* 6. *The mechanical effects produced by the unstratified upon the stratified rocks.* In the vicinity of veins and irregular masses of the unstratified rocks, the stratified ones are bent and twisted in every conceivable manner, and sometimes broken entirely.

*Proof,* 7. *The chemical effects produced upon the stratified rocks by the contact of the unstratified.* These effects are precisely the same as those produced by dykes of recent lava.

*Prin.* The greater degree of crystalization in the older unstratified rocks, may be explained, by supposing a more perfect fusion of the materials than in recent lavas, and greater slowness in cooling, under perhaps the more powerful pressure of a deep ocean.

## Temperature of the Globe.

*Prin.* The principal circumstances that determine the temperature of the globe and its atmosphere, are the following: 1. Influence of the sun. 2. Nature of the surface. 3. Height above the ocean. 4. Temperature of the celestial spaces around the earth. 5. Temperature of the interior of the earth, independent of external agencies.

1. *Solar Heat.* The solar rays exert no influence as a general fact, at a greater depth than about 100 feet. (Baron Fourier mentions 130 feet as the maximum depth: Poisson fixes it at 76 feet. *Am. Jour. Science, Vol.* 32. *p.* 5. *and Vol.* 34. *p* 59.)

2. *Nature of the Surface.* The radiating and absorbing power of land is quite different from that of water. Ice and snow are still more different; and the nature of the soil affects sensibly its power to imbibe or give off heat. Hence low islands have a higher temperature than large continents in the same latitudes; and the ocean possesses a greater uniformity of climate than the land.

3. *Height above the Ocean.* The temperature of the air diminishes one degree (Fahr.) for 300 feet of altitude: two degrees for 595 feet: three degrees for 872 feet: four degrees for 1124 feet: five degrees for 1347 feet: and six degrees for 1539 feet: Hence at the equator perpetual frost exists at the height of 15.000 feet, diminishing to 13.000 feet at either tropic.

4. *Temperature of the Celestial Spaces around the Earth.* This cannot be much less than the temperature around the poles of the earth; where the solar heat has scarcely no influence. Now the lowest temperature hitherto observed on the globe, (at Mellvile Island,) is 58° below zero: and this has been assumed as the temperature of the planetary spaces. Hence it follows that there must be a constant radiation of heat from the earth into space.

5. *Temperature of the Interior of the Earth, Independent of External Agencies.*

*Prin.* In descending into the earth, beneath the point where it is affected by the solar heat, we find that the temperature regularly and rapidly increases.

*Proof* 1. The temperature of Springs which issue from the rocks in mines, as shown in the following Table.

| COUNTRIES. | MINES. | Depth in Feet. | Temperature. | Mean Temp. at Surface. | Depth for one deg. Fahrenheit. |
|---|---|---|---|---|---|
| Saxony. | Lead and Silver Mine of Junghohe Birk | 256 | 48°9 | 46.9 | 102.4 |
| | do of Beschertgluck, | 712 | 54.5 | 46.4 | 87. |
| | do do | 840 | 56 8 | | 80.7 |
| | do Himmelfahrt, | 735 | 57.9 | | 63.9 |
| | do Kuprinz, | 634 | 80.1 | | 18.8 |
| Brittany, | do Poullauen, | 128 | 53.4 | 52.7 | 182. |
| | do do | 246 | 53.4 | | 351. |
| | do do | 459 | 58.3 | | 82. |
| | do Huelgoet, | 197 | 54. | 51.8 | 89.5 |
| | do do | 262 | 59. | | 36.4 |
| | do do | 394 | 59. | | 54.7 |
| | do do | 755 | 67.5 | | 48.4 |
| Cornwall, | Dolcoath Mine, | 1440 | 82. | 50. | 45. |
| Mexico, | Guanaxato, Silver Mine. | 1713 | 98.2 | 68.8 | 45.8 |

*Proof* 2. *Temperature of the Rock in Mines;* as shown in the following Table.

| COUNTRIES. | MINES. | Depth in Feet. | Temperature Observed. | Mean temp. of Surface. | Depth for one degree. |
|---|---|---|---|---|---|
| | 1. *In loose matter near the face of the Rock.* | | | | |
| Cornwall, | United Copper Mines, | 1142 | 87°.4 | 50° | 30.5 |
| | | 1201 | 88. | | 31.1 |
| Carmeaux France. | Coal Pit of Ravin, | 597 | 62.8 | 52 | 55.3 |
| | do of Castellan, | 630 | 67.1 | 52 | 40 8 |
| Littry, do. | do of St. Charles, | 325 | 61. | | 36 1 |
| Decise, do. | do of St. Jacobi, | 351 | 64. | | 29.2 |
| do. do. | do do | 561 | 71 7 | | 28.5 |
| | 2. *In the Rock near its surface.* | | | | |
| Saxony, | Mine of Beschertgluck, | 591 | 52.2 | | 101. |
| | do do | 813 | 59. | 46.4 | 67. |
| | do do | 236 | 47.7 | | 174.7 |
| | do do | 552 | 55. | | 63.7 |
| | do do | 880 | 59. | | 69.8 |
| | do do | 1246 | 65.7 | | 64.4 |
| | 3. *Three feet three inches within the rock.* | | | | |
| Cornwall, | Dolcoath Mine. Register kept 18 months | 1381 | 75.6 | 50. | 54. |
| Saxony, | Lead and Silver Mine of Kurpinz. | 413 | 59.6 | | 31.3 |
| | do do | 686 | 62.5 | | 42.6 |
| | do do | 1063 | 67.7 | | 49.9 |

*Proof* 3 *Temperature of Artesian Wells*, as shown in the following Table.

| LOCALITIES. | Depth in Feet. | Mean Temp at Surface. | Temp. of Wells | Depth for 1 degree in Feet. |
|---|---|---|---|---|
| Paris: Fountain de la Garde St. Ouen. | 216 | 51.°1 | 55.°2 | 52.7 |
| Dept. du Garde et des Pas Calais Fountain Artesienne de Marguetta. | 184 | 50.5 | 54.5 | 46. |
| Do. d'Aire. | 207 | | 55 9 | 38.3 |
| Do. de St. Venant. | 328 | | 57.2 | 49. |
| Sheerness, England, mouth of the Medway. | 361 | 50.9 | 59.9 | 40.1 |
| Tours. | 459 | 52.7 | 63 5 | 42.5 |
| A well at La Rochelle. | 369 | 53.4 | 64.6 | 33. |
| Near Berlin, Prussia at, | 675 | 49.1 | 67 66 | 36.3 |
| Do. the same well at, | 516 | | 63 95 | 34.7 |
| Do. do at, | 392 | | 62.82 | 28.5 |
| Near N. Brunswick, N. Jersey, at the depth, | 250 | | 52. | 72. |
| Do. at, | 394 | | 54. | |
| South Hadley, Mass. | 180 | 46.34 | 52. | 32. |

*Proof* 4. *Thermal Springs.* Vast numbers of these occur in regions far removed from any modern volcanic action; generally upon lofty mountain ranges; as upon the Alps, the Pyrenees, Caucasus, the Ozark mountains in this country, where are nearly 70, &c Their temperature varies from about summer heat nearly up to that of boiling water. Nor can their origin be explained without supposing a deep seated source of heat in the earth. This argument is not indeed, as direct and conclusive as those previously mentioned: But it confirms the others.

*Proof* 5. *The existence of numerous deep seated volcanos.* This argument is of the same kind as the last, and does not need any farther illustration here.

*Proof* 6. *Not one exception to this increase of internal temperature has ever occurred, where the experiment has been made in deep excavations.*

*Inference* 1. The increase of temperature from the surface of the earth downwards, does not appear to be at the same rate in all countries. The mean of all the observations recorded in the preceding tables, which have been made in England, gives 44 feet for a change of one degree. In some mines in France the increase is much slower, and in a few it is faster. The mean is reckoned at about 45 feet for each degree. In Mexico, according to the only observation given above, it is 45 8 feet. In Saxony it is considerably greater, not far from 65 feet to a degree. The few observations in this country given in the preceding table, indicates an increase of 54 feet to a degree.

*Inference* 2. At this rate, and assuming the temperature of the surface to be 50°, a heat sufficient to boil water would be reached at the depth of 5962 feet, or a little more than a mile: a heat of 7000°, sufficient to melt all known rocks, would be reached at 48 miles: and at the center of the earth, it would amount to 577.000°. *Cordier's Essay on the Temperature of the Interior of the Earth. Amherst*, 1828, *p.* 73. *Moffatt's Scientific Class Book, by Prof. Johnson, Philadelphia*, 1836, *Vol.* 2, *p.* 311.

*Inference* 3. From the preceding facts, and other collateral evidence, it has been inferred that all the interior of the earth, except a crust from 50 to 100 miles thick, is at present in a state of fusion: that originally the whole globe was melted, and that its present crust has been formed by the cooling of the surface by radiation.

*Remark.* Fig. 273, is intended to represent the proportion of melted and unmelted matter in the

earth, agreeably to the above inference; and on the supposition that the solid crust is 100 miles thick. This is shown by the broad line that forms the circumference. According to the mean increase of subterranean heat stated above, this crust should be only half as thick.

Fig. 273.

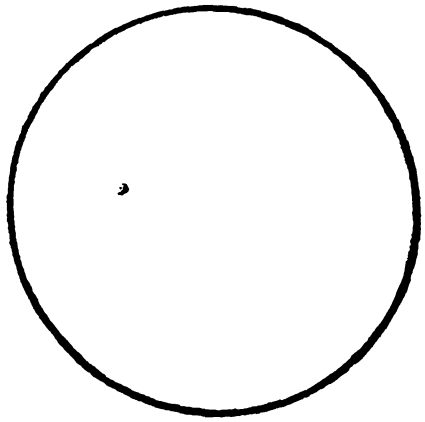
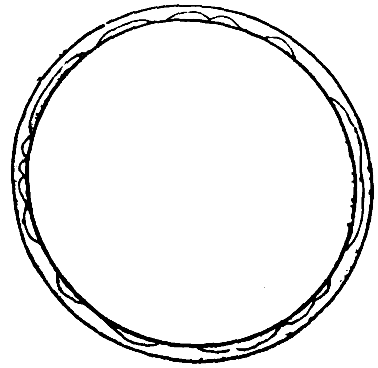


Fig. 274.



## *Proofs of this Inference.*

*Proof* 1. Until some fact can be adduced showing that the heat of the earth ceases to increase beyond a certain depth, nothing but hypothesis can be adduced to prove that it does not go on increasing, until at least the rocks are all melted: for when they are brought into a fluid state, it is not difficult to see how the temperature may become more equalized through the mass, in consequence of the motion of the fluid matter; so that the temperature of the whole may not be greatly above that of fused rock. Now if the hypothesis of internal fluidity have other arguments (which follow below) in its favor, while no facts of importance sustain its opposite, the former should be adopted.

*Proof* 2. It appears from the experiments and profound mathematical reasoning of Baron Fourier, that even admitting all the internal parts of the earth to be in a fused state, except a crust of 30 or 40 miles in thickness, the effect of that internal heat might be insensible at the surface, on account of the extreme slowness with which heat passes through the oxidized crust. He has shown that the excess of temperature at the surface of the earth, in consequence of this internal heat, is not more than 1-17th of a degree, (Fahr.) nor can it ever be reduced more than that amount by this cause. This amount of heat would not melt a coat of ice 10 feet thick, in less than 100 years: or about one inch per annum. The temperature of the surface has not diminished on this account, during the last 2000 years, more than the 167th part of a degree: and it would take 200.000 years for the present rate of increase in the temperature as we descend into the earth to increase the temperature at the surface one degree: that is supposing the internal heat to be 500 times greater than that of boiling water. From all which it follows, that if internal heat exist, it has long since ceased to have any effect practically upon the climate of the globe. *Annals de Chimie et de Physique No.* 27. *American Journal of Science, Vol.* 32. *p.* 1. *Phillip's Treatise on Geology, Vol.* 2. *p.* 275.

*Proof* 3. The existence of 300 active volcanos, and many extinct ones, whose origin is deep seated, and which are connected over extensive areas.

## *Other Hypotheses of Volcanic Action.*

*Hypothesis of the Metalloids* This hypothesis, originally proposed, though subsequently

abandoned, by Sir Humphrey Davy, supposes the internal parts of the earth, whether hot or cold, fluid or solid, to be composed in part of the metallic bases of the alkalies and earths, which combine energetically with oxygen whenever they are brought into contact with water, with the evolution of light and heat. To these metalloids water occasionally percolates in large quantities through fissures in the strata, and its sudden decomposition produces an eruption. Dr. Daubeny, the most strenuous advocate of this theory at the present time, has brought forward a great number of considerations which render it quite probable that this cause may often be concerned in producing volcanic phenomena, even if we do not admit that it is the sole cause. *Daubeny on Volcanos.*

*Proof* 4. *The Spheroidal Figure of the Earth.* Its form is precisely that which it would assume, if while in a fluid state, it began to revolve on its axis with its present velocity; and hence the probability is strong that this was the origin of its oblateness. But if originally fluid, it must have been igneous fluidity: for since the solid matter of the globe is at present 50.000 times heavier than the water, the idea of aqueous fluidity is entirely out of the question.

*Proof* 5. *The tropical and ultra tropical character of organic remains found in high latitudes.* If the globe has passed through the process of refrigeration, as the hypothesis of original igneous fluidity implies, there must have been a time, before reaching its present statical condition, when the surface had the high temperature denoted by these remains: and that period must have been very remote; since no essential change of temperature from internal causes has taken place for thousands of years. A climate, also, chiefly dependent on subterranean agency, would be more uniform over the whole globe, than one dependent upon solar influence: and such appears to have been the climate of those remote ages. Hence we may reasonably impute that temperature to internal heat; if some other more probable cause cannot be found.

*Proof* 6. *The fact that nearly all the crust of the globe has been in a melted state.* For if the entire crust of the globe has been fused, it is a fair presumption that it was the result of the fusion of the whole globe.

*Proof* 7. *This theory furnishes us with the only known adequate cause for the elevation of mountain chains and continents.*

## *Elevation by Central Heat.*

*First Mode.* It is possible to conceive that volcanic power, acting as at present, but with vastly greater intensity, might have lifted up continents: for their elevation, in part at least, appears to have been the result of local forces acting beneath the earth's crust.

*Second Mode.* A more probable hypothesis, suggested by Beaumont, imputes the present ridged and furrowed condition of the earth's surface to *a collapse of its consolidated crust upon its contracted interior nucleus.* This is illustrated by fig. 274.

The outer circle represents the crust of the earth, after it had become consolodated above the liquid mass within. This heated nucleus would go on contracting as it cooled, while the crust would remain nearly of the same size. At length when it became necessary for the crust to accommodate itself to the nucleus, contracted for instance to the inner circle, it could do this only by falling down in some places and rising in others; as is represented by the irregular line between the two circles. Thus would the surface of the earth become plicated by the sinking down of some parts by their gravity, and the elevation of correspondent ridges by the lateral pressure. The principal ridges thus produced, must coincide very nearly with a great circle: and as the earth's crust made successive efforts to accommodate itself to the constantly contracting nucleus, ridges would be produced in different directions, crossing one another; and thus the various systems of elevation known to exist on the globe, be formed at various epochs.

## *Origin of the Primary Stratified Rocks.*

*Remark.* The way has not previously been prepared for a full understanding of the two hypotheses concerning the origin of the primary stratified rocks; because both of these depend more or less upon internal heat.

*First Hypothesis.* According to this hypothesis the stratified primary rocks are merely the detrital or fossiliferous rocks altered by heat. As these accumulated at the bottom of the ocean, being much poorer conducters of heat than water, they would confine the internal heat that was attempting to escape by radiation, until it became so great as to bring the matter into a crystaline state: but not great enough to produce entire fusion, so as to destroy the marks of stratification.

*Arguments in favor of this Hypothesis.* 1. Numerous facts show that the molecular constitution of solid bodies may undergo great changes, without much change of the general form; and even without any great elevation of temperature. Thus the heat of the sun alone, will change prismatic crystals of zinc into octahedrons; and the same takes place with sulphate of nickel. (*Connection of the Physical Sciences by Mrs. Sommerville, p.* 171.) Indeed, Dr. Macculloch says he has completely proved by experiments, that "every metal can completely change its crystaline arrangements while solid, and many of them at very low temperatures." (*System of Geology, Vol.* 1. *p.* 190.) Analogous changes have taken place in sandstone beneath trap rocks: in trap rocks after they have become solid; and in solid glass. Hence the presumption is in favor of these internal changes in rocks of mechanical origin from internal heat.

2. The heat requisite for the conversion of detrital into crystaline rocks, without destroying the stratified structure, may have been derived either from an internal heated nucleus in the earth, when the crust was thinner than at present, as it was during the period in which the primary strata were deposited, or from local nuclei of heat, propagated upwards through detrital deposits, according to the theory of Prof. Babbage.

3. Geology furnishes numerous examples, in which the mechanical or fossiliferous rocks have been converted by heat into primary crystalized rocks in limited spots by the agency of heat. When dykes of granite, porphyry, trap rocks, or recent lava, pass through detrital deposits, for a certain distance on the sides of the dyke, these conversions have taken place. Chalk and earthy limestone are in this manner in Ireland, converted into crystalized marble: and the same effect was produced upon chalk by heating it powerfully in a sealed gun barrel. Experimental proof has also been furnished by the chemist, that quartz rock is merely sandstone altered by heat; as is shown also at Salisbury Craig, Teesdale, and Shropshire in Great Britain, where sandstone and basalt come in contact. In Shetland argillaceous slate, when in contact with granite, is changed into hornblende slate.

4. The primary stratified rocks still retain marks of a mechanical origin. The general appearance of gneiss and mica slate is that of fragments of crystals, more or less worn and rounded, and then recemented by heat. But real conglomerates occur which yet have all the characters of the primary stratified rocks, except perhaps gneiss.

*Objections.* 1. There is little probability that detritus is conveyed to the bottom of the ocean in quantities sufficient to cause such an accumulation of internal heat, as would convert mechanical into crystaline rocks:—a degree of heat nearly equal to that which would melt them. True, the heat would accumulate in these detrital deposits to a certain degree: but not beyond what exists in the solid crust of the earth generally; and this would require us to descend many miles, before a temperature would be reached sufficient for the purpose. Unless, therefore, this theory supposes a much higher temperature on the globe when this change took place, than at present, (and most of its advocates deny this,) the requisite heat could not have been obtained,

especially as in many cases the primary rocks extend to the surface, and do not appear to have ever been covered with newer ones; so that there must have been heat enough to produce this transformation immediately beneath the waters of the ocean.

2. The difference in chemical composition between the primary and the newer rocks, is opposed to the idea that the former are only modifications of the latter. For we find that some of the ingredients, lime and carbon for instance, are far more abundant in the newer, than in the older rocks. This difference points of course to a different origin.

3. If all the stratified primary rocks are metamorphic, we ought to find in them occasionally, especially in the limestones, traces of organic remains. For examples are not uncommon, in which the traces of such remains are found in calcareous rocks which have become perfect crystaline limestone, as in the encrinal limestone: and in other rocks which are converted into vesicular trap by the agency of heat. It is incredible, therefore, that if the remains of animals and plants once existed in these rocks, as numerous as they now exist in the secondary rocks, they should have all vanished; since it is certain, that the heat which produced the metamorphosis, was not great enough to obliterate the stratification.

*Second Hypothesis.* This hypothesis supposes the primary stratified rocks to have been formed partly in a mechanical and partly in a chemical mode, by aqueous and igneous agency, when the temperature of the crust of the globe was very high, and before organic beings could live upon it.

*Arguments in favor of this Hypothesis.* 1. It shows why amid so much evidence of chemical agency, in the formation of the primary rocks, there is still so much proof of the operation of mechanical agencies. For in that state of the globe, when its crust had cooled only so far as to allow water to exist upon it in a fluid state, volcanic agency must have been far more active than at present: and consequently the agitated waters must have worn away the granite at their bottom extensively. But as the heated waters would contain a great deal of silica, and other ingredients which would readily fall down as chemical deposits, the abraded materials would be consolidated before they had become entirely rounded into pebbles; so that the compound might, upon the whole, be regarded as of chemical origin; and yet not be destitute, as gneiss and mica slate are not, of the marks of attrition. Indeed, it would be strange, if in some instances the attrition did not proceed so far as to produce the materials for a perfect conglomerate; as the facts mentioned under the last hypothesis show was sometimes the fact.

2. It shows us why silicates predominated in the earlier periods of the globe; and why limestone and carbon were more abundant at later periods. Thermal waters often contain an abundance of silica in solution; but cold water never does. Again, by heating water to the boiling point, the carbonic acid is all driven off: and without this acid, carbonate of lime could not be held in solution to much extent; and farther, hot water will dissolve much less quicklime than cold; the proportion being as 778 to 1270. Hence the heated seas of those early times would contain and depcsit more of silica, but less of lime, or carbonate of lime, than under existing circumstances. Another cause why less of lime is found in the older rocks, is, that probably it was then less in quantity in a solyble state; since it would seem to have been derived, in part at least, from organic beings which did not then exist.

3. It explains the absence of organic remains in the primary stratified rocks. It shows that the temperature was too high, and the surface too unstable, to allow of the existence of animals and plants. And if they had existed in as great abundance as at present—an assumption which is made by the preceeding hypothesis—it is incredible that some traces of them should not remain: for if the fusion of these rocks was not so entire as to obliterate all marks of mechanical agency, if, in fact, perfectly rounded pebbles still occur in them, there is no reason why the harder parts of animals should not also remain: We have examples where the traces of organic re-

mains exist in rocks, that have been almost entirely fused—at least so much melted, as in the case of a vegetable stem in trap, in the valley of the Connecticut, that it is converted into decided vesicular amygdaloid; and yet its vegetable character can scarcely be doubted. (No. 2590, State Collection) We may hence infer, with no little confidence, that organic life did not exist on the globe when the primary rocks were in a course of deposition, and this hypothesis explains the reason.

4. It explains too the reason why carbon is much less abundant in the older than in the newer rocks. Organic beings are undoubtedly the immediate source of most of the carbon in the rocks, and of course it would be found in small quantities where neither animals nor plants existed.

5. It explains the imperceptible gradations of gneiss into granite, which we often witness. For if thick beds of gneiss were deposited upon the granite, under the circumstances supposed by the hypothesis, it is easy to conceive how the internal heat should accumulate in the manner explained by Prof. Babbage, so as to melt the granitic crust anew, and to extend the fusion into the lower beds of the gneiss; at least so as to produce an almost entire obliteration of the lines of stratification, and form numerous *niduses* of perfect granite in the gneiss. This hypothesis explains the passage of these two rocks into each other, better than the first hypothesis; because it supposes a higher temperature beneath and upon the earth's crust at the time of the formation of the gneiss.

## *Intensity of Action in the Causes of Geological Change.*

*First Theory.* Mr. Lyell contends that the causes of geological change now operating upon the globe, with no increase of intensity, that is, acting with no more energy than at present, are sufficient to account for all the revolutions which the crust of the earth has undergone. He admits of no irregularities or catastrophes greater than now take place: and supposes that effects which transcend any single effect of existing causes, have been the result of repetitions, sometimes almost endless, of present agencies. In other words, he supposes that things have remained from the beginning subject to no greater changes than they experience at the present time. To prove these positions is the great object of his able work on the Principles of Geology.

*Proof.* 1. It is agreed on all hands, that the nature of geological causes has been the same in all ages; although even as late as the time of Cuvier, he says that "none of the agents nature now employs were sufficient for the production of her ancient works."

2. An indefinite repetition of an agency on a limited scale, can produce the same effects as a paroxysmal effort of the same agency, however powerful; provided the former is able to produce any effect, as for instance, in the accumulation of detritus, the elevation of continents, the dislocation of strata, &c. Now it is unphilosophical to call in the aid of extraordinary agency, when its ordinary operation is enough to explain the phenomena.

3. Nearly every variety of rock found in the crust of the globe, has been shown to be in the course of formation by existing aqueous and igneous agencies: and if a few have not yet been detected in the process of formation, it is probably because they are produced in places inaccessible to observation.

*Second Theory.* This theory admits that no causes of geological change, different in their nature from those now in action, have ever operated on the globe: in other words, that the geological processes now going on, are in all cases the antitypes of those which were formerly in operation; but it maintains that the existing causes operate now in many cases, with less intensity than formerly.

*Proof* 1. The spheroidal figure of the earth and other facts already detailed, seem to render almost certain the former fluidity of the globe. Now whether that fluidity was aqueous or igneous, or both in part, it is certain that the agencies which produced it must have operated in earlier times with vastly greater intensity than at this day, and that their energy must have been constantly decreasing from that time to the present.

2. Still more direct is the evidence from the character of organic remains in high latitudes, of the prevalence of a temperature in early times hotter than tropical: too warm, indeed, to be explained by any supposed change of levels in the dry land. And if this be admitted, heat must have been more powerful in its operation than at present; and this would increase the aqueous, atmospheric and organic agencies of those times.

3. No agency at present in operation, without a vast increase of energy, is adequate to the elevation, several thousand feet, of vast chains of mountains and continents; such as we know to have taken place in early times. A succession of elevations by earthquakes, repeated through an indefinite number of ages, the vertical movements being only a few feet at each recurrence, is a cause inadequate to the effect, if we admit that earthquakes have exhibited their maximum energy within historic times. Besides, it is difficult to conceive how a Continent could be sustained several thousand feet high, unless melted matter be forced in beneath its crust. But earthquakes, and even the whole amount of volcanic power, if the doctrine of internal heat be rejected, could not supply any such prop. If we could suppose a succession of earthquakes, acting for thousands or millions of years along some anticlinal axis of great length, we have reason to suppsoe from their known operation, that sometimes they would elevate, and sometimes sink down the surface; so that the final resultant would be probably little change of level, and not an elevation like the Andes or the Himmalayah mountains.

4. In a majority of cases the periods of disturbance on the globe appear to have been short compared with the periods of repose that have intervened: as is obvious from the fact that particular formations have the same strike and dip throughout their whole extent: unless some portions have deen acted upon by more than one elevatory force: and then we find a sudden change of strike and dip in the formations above and below. Whereas, had any of the causes of elevation now in operation lifted up these formations by a repetition of their present comparatively minute effects, there ought to be a gradual decrease in the dip from the bottom of the formations, unless some strata are wanting. At the periods of these elevatory movements, therefore, the force must have been greater than any that is now exerted, to produce analogous effects.

5. The sudden and remarkable changes in the organic contents of the strata, as we pass from one formation to another, even when none of the regular strata are wanting, coincides exactly with the supposition of long periods of repose, succeeded by destructive catastrophes. Nor is the supposition that species of animal and plants have become gradually extinct, and have been replaced by new species, by a law of nature during periods of repose, sustained by any facts that have occured within the historic period: no example having been discovered of the creation of a new species by such a law; and not more than one or two (the Dodo and Apteryx) of the extinction of a species.

6. We have no evidence that the most important of the older rocks, both stratified and unstratified, are produced by any causes now in operation. That they may be produced deep in the earth, where igneous causes are still in intense operation, is a plausible hypothesis, but unsustained by a single example of the production of mica slate, gneiss, granite, or sienite. The highly crystaline and in other respects peculiar character of these rocks, as well as their entire deficiency of traces of organic existence, when they were formed, point to a state of the globe, different from the present, but different only because existing causes especially heat operated then with greater energy than at present.

7. Diluvial action, since the deposition of the tertiary strata, requires for its explanation a

greater intensity of action in existing geological agencies than is known at the present day. This point, however, has been so fully discussed that nothing more need be added here.

8. Upon the whole, with the exception of diluvial action, were we to confine our attention to the tertiary and alluvial strata, it might be possible to explain their phenomena by existing causes, operating with their present intensity. But when we examine the secondary and primary rocks, we are forced to the conclusion that this hypothesis is inadequate: and that we must admit a far greater intensity in geological agencies in early times than at present.

## *Metallic Veins.*

*Descrip.* The metallic matter, called *ore*, rarely occupies the whole of the vein: but is disseminated more or less abundantly through the quartz, sulphate of baryta, wacke, granite, &c. which constitutes the greater part of the vein, and is called the *gangue*, *matrix*, or *veinstone*.

*Descrip.* Metallic like other veins, vary very much in width, both in a vertical and a horizontal direction. They are of unknown depth; for scarcely ever have they been exhausted downward.

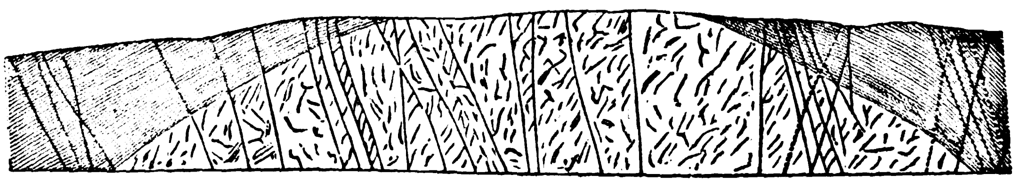
*Descrip.* In all cases metallic like other mineral veins, are filled with matter different from the rocks which they traverse. Their width is very various; from a mere line, up to some hundreds of feet. The metallic veins of Cornwall vary from an inch to 30 feet in width. The contents are sometimes arranged in successive and often corresponding layers on each side.

*Descrip.* The contents of metalliferous veins often vary in the same vein, in different rocks, through which they pass perpendicularly and in the direction of the vein. Their width also varies in the same manner.

*Descrip.* Metallic veins are most numerous in primary and transition rocks. No vein is worked in Great Britian above the new red sandstone. Nor are any explored of much importance, above the carboniferous limestone.

*Descrip.* As a general fact, metallic veins are most productive near the junction of stratified and unstratified rocks. Fig. 276, is a section of tin and copper veins near Redruth in Cornwall. They generally pass from the killas, or slate, into the granite beneath. The section reaches to the depth of 1200 feet. The dotted lines represent the tin lodes, (veins) and the continuous lines, the copper lodes.

Fig. 275.




*Metalliferous Veins in Cornwall, England.*

## *Theories to explain the Repletion of Veins in General.*

1. Werner supposed that veins were fissures filled by aqueous infiltration from above. 2. Hutton supposed that veins were filled by melted matter injected from beneath. 3. Prof. Sedgwick supposes some veins to have been produced by chemical segregation from the rock in which they occur, while that was in a yielding state. 4. Mr. Fox and M. Becquerel refer the origin of many metallic veins to electro-chemical agencies, which are operating at the present day, to transfer the contents of veins even from the solid rocks, in which they are disseminated, into fissures in the same. 5. M. Neckar and Dr. Buckland suggest, that some mineral veins may have been filled by the sublimation of their contents into fissures and cavities of the superincumbent rocks, by means of intensely heated mineral matter beneath.

# APPENDIX.

## A CATALOGUE OF SPECIMENS OF ROCKS AND MINERALS ILLUSTRATING THE REPORT OF A GEOLOGICAL SURVEY OF MASSACHUSETTS.

### *Collected by Order of the Government of the State.*

The State Collection contains two sets of specimens, both numbered from unity onward. The smallest set consists chiefly of soils, clays, and marls; and all the specimens are contained in glass bottles, ticketed and sealed, and extending to 227. In the other set, which contains 2646 specimens, the numbers are usually attached directly to the specimens, though some of them are in bottles. When reference is made to this Collection in the preceeding Report, the letter *b*, is annexed to the specimen belonging to the first or smallest set, except the soils proper, which amount to 152: and which can hardly be confounded with the specimens of the other set. In the second set considerable irregularity will be perceived in the order of the numbers, occasioned by the re-survey, which made it necessary to add a second set of numbers to the first, under the different rocks. This could not be avoided without numbering over the whole Collection anew.

About 130 of the specimens have been smoothed or polished; and this is mentioned under each number, where such is the case. Those specimens that have been only smoothed, have been varnished; and this process will need to be renewed occasionally. I found that in this way the true character of the rock could be brought to light quite as distinctly as by polishing; and thus the expense was considerably reduced.

*First Set.*

No. 1 to 125, Soils from various parts of the State: for their character and localities see Table, p. 41.

| *No.* | | |
|---|---|---|
| 126 | Muck Sand, | Sunderland. |
| 127 | do | Bradford. |
| 128 | do | W. Springfield. |
| 129 | do | Hadley. |
| 130 | do | Sheffield. |
| 131 | do | Northfield. |
| 132 | do | Amherst. |
| 133 | do | Leominster. |
| 134 | Marsh Mud, | Cambridge. |
| 135 | do | Newburyport. |
| 136 | do | Medford. |
| 137 | Diluvial Clay. | Newbury. |
| 138 | do | Manchester. |
| 139 | do | Northfield. |
| 140 | do | Sunderland. |
| 141 | do | Amherst. |
| 142 | do | Kingston. |
| 143 | do | Lowell. |
| 144 | Tertiary do | Gay Head. |

| *No.* | | |
|---|---|---|
| 145 | Porcelain Clay | Norwich |
| 146 | Marly do | Williamstown. |
| 147 | do do | North Adams. |
| 148 | Marl, Buck's farm, | Stockbridge. |
| 149 | do | Pittsfield. |
| 150 | do | W. Stockbridge. |
| 151 | do | Stockbridge, N. E. of Village. |
| 152 | do | Pittsfield, S. W. of Village. |
| 153 | do | Lee, Sedgwick's Mills. |
| 154 | Calcareous Diluvium, Chicopee Falls. | |
| 155 | Springfield, Water Shops. | |
| 156 | West Springfield. | |
| 157 | Siliceous Marl, (Bergmehl, or mountain meal,) Spencer. | |
| 158 | Green Sand, Marshfield. | |
| 159 | Apothemite, Newbury. | |
| 160 | Decomposing Trap Rock, Mt. Holyoke. | |
| 161 | Yellow Ochre, Athol. | |
| 162 | do | Monroe. |

163 Yellow Ochre Newbury.
164 do New Marlborough.
165 Red do do
166 Moulding Sand, Foxborough.
167 do ? Montague.
168 Decomposed Granite, Norwich.
169 Siliceous Marl, or Fossil Infusoria, Barre.
170 do Andover.
171 do W. Bridgewater.
172 Marl, Lee, S. Bassett's Bed, near the surface.
173 do do do 10 feet deep.
174 do do C. Bassett's Bed.
175 do do Sedgwick's Mills.
176 to 201, Soils: for characters and localities, See Table, p. 41.
203 Marl, Stockbridge, N. E. of Village.
204 do Farmington, Ct.
205 Diluvial Clay, Palmer, S. part.
206 do Springfield, under the river.
207 Green Sand, New Jersey.
208 do Gay Head.
209 do Blackish variety, N. Jersey.
210 White Sand, Gay Head.
211 Decomposed Granite, do.
212 do New Jersey. (Moulding Sand for Brass.)
213 Moulding Sand, near Albany N. Y.
214 do ? Shutesbury.
215 do Connecticut.
216 Yellow Ochre, Bedford.
217 do Harwich.
218 Moulding Sand, New York State.
219 Marly Clay, South Lee.
220 Diluvial Clay, Plymouth.
221 Chromate of Potassa from the Chester Chromite of Iron.
222 Chromate of Lead, from do.
223 Bichromate of do from do.
224 Geate of Alumina from Soils.
225 do of Lime, from do.
226 do of Potassa from do.
227 Geine from do.

*Second Set.*

STRATIFIED ROCKS.—(*Alluvium.*)

1 Alluvial Sand, Lock's Pond, Shutesbury.
2 Fossil Infusoria, (polishing powder,) do
3 and 4 Peat, Pittsfield.
5 do Leverett.
6 do Hadley.
7 and 8 do Weston.
9 do Northborough.
10 do Shrewsbury.
11 do Wilbraham.
12 Marl, Pittsfield.
13 Planorbis parvus and bicarinatus in marl, Pittsfield.
14 do trivolis in do do
15 Lymnaea heterostropha and catascopium, do
16 Cyclas (*nondescript*,) in marl, Pittsfield.
17 Bog Ore, Brookfield.
18 do New Braintree.
19 do Petrified Carex, do
20 Black Wad, (earthy oxide of manganese,) Conway.
21 do Leverett.
22 do Whately.
1551 Pyrope Sand, Brimfield.
1552 Recent Calcareous Breccia, W. Stockbridge.
1553 Cadmia, Van Deusenville Furnace, Stockbridge.
1554 Manganese from the hearth of the iron furnace, Richmond.
1555 Peat, Sunderland.
1556 do Westborough.
1557, 1558, do Lee.
1559 do Hubbardston.
1686 Wad, West Stockbridge.
2504, 2505, Calcareous Concretions in Cave Lanesborough.

## *Diluvium.*

23 Diluvium, Leominster.
24 do ferruginous do
25, 26, 27, and 28 do consolidated, Pownal, Vt.
29 Pyrula Carica, (47 feet below the surface,) Nantucket.
30 do do worn, Nantucket.
31 Natica Heros, do
32 Crepidula Fornicata. do
33 Venus Castanea, do
34 Mactra, do
35 Clay, Amherst.
36 Sand, do
37 and 38 Clay, Leominster.
39 do Loamy, do
40 Sand, do
41 Argillo-Calcareous Concretions in Clay, Claystones, South Hadley.
42, 43, and 44 do Amherst.
45 do Hadley.
46 do South Hadley.
47 and 48 Ferruginous do in Clay and Loam, Deerfield
49 and 50 do South Hadley Canal.
51 do do Deerfield.
52 do do Charlestown.
53 Brown Hematite, Stalactical, Richmond.
54 do do W. Stockbridge.
55 do Pavonine, do
56 do Compact, Richmond.
57 do Mammillary, Lenox.
58 do With Yellow Ochre, W. Stockbridge.
59 do With Red Oxide of iron, do
60 do With radiated manganese do
61 Gibbsite, Richmond.
1560 Calcareous Diluvium, Springfield.
1561 Diluvial Sand, Plymouth.
1562 do Clay, W. Springfield.

1563 Diluvial Clay, W. Stockbridge.
1564 do Palmer Rail Road.
1565 do Taunton.
1566 to 1568, do In Rhomboidal mas es, West Springfield.
1683, 1684, do do Deerfield.
2502 Clay used for Fuller's Earth, Northampton.
1569 to 1584, Ferruginous Concretions in Diluvial Clay, Deerfield.
1585, 1586 do Hadley.
1587, 1588 do Deerfield, perhaps human bones formed the nucleus.
1589 to 1591 do Manchester.
1592 to 1629 Claystone Concretions, Hadley.
1630 to 1638 do W. Springfield, near South Hadley Falls.
1639 to 1646 do Amherst.
1647 to 1650 do Agawam in W. Springfield.
1651 to 1655 do North Adams.
1656 to 1658 do Wethersfield, Ct.
1659 to 1664 do Windsor, Ct.
1665 to 1668 do Montague.
1669 to 1682 do Deerfield, near Sunderland Bridge.
1683 and 1684. See No. following 1568.
1685 Galena from diluvium, Dedham.
1687 Pyrolusite, Iron Ore Bed, W. Stockbridge.
1688 Ferruginous Conglomerate, Montague.
1689 Carbonate of Iron, (Sphærosiderite,) Iron Ore Bed, W. Stockbridge.
1690 Fibrous Hematite, Richmond.
1691 Stalactical Hemitite with dendrites probably of manganese, W. Stockbridge.
1692, 1693 do Richmond.
1694 to 1696 Mammillary do Richmond.
1697 to 1700 Compact do do
1700 to 1703 Vesicular do do
1704 Scaly Red Oxide of Iron from a bowlder, Carver.
1705 Gibbsite on Hematite, W. Stockbridge.
2501 Hornstone, bowlder, Plymouth.
2512 to 2527 Consist of Sand, Gravels and Clays, from borings beneath Connecticut River at Springfield, executed by Major Whistler, where the Western Rail Road crosses it. The first eight specimens were taken from the depths indicated at the abutment on the east bank shown on the Section, Fig. 67, by the perpendicular line most to the left. The second eight were taken from beneath the fourth Pier shown by the fifth perpendicular line reckoning from left to right.
2512 Coarse Sand, Abutment, depth 5 ft. 9 in.
2513 Clay, not marly, do do 7 ft.
2514 do do do do 10 ft. 9 in.
2515 do Marly, do do 20 ft. 9 in.
2516 do do do 25 ft. 9 in.
2517 do do do 30 ft 9 in.
2518 Fine Sand slightly calcareous, 32 ft. 9 in.
2519 Coarser do and gravel do do 39 ft. 5 in.
2520 Coarse Sand, Pier No. 4. Depth 5 ft.
2521 Muck Sand, not calcareous. 6 ft. 6 in.
2522 Fine Clay, Marly do do 20 ft.
2523 Muck Sand, very marly do 30 ft.
2524 Coarse Marly Sand. do 34 ft.
2525 Gravel. do 35 ft.
2526 Coarse Sand and Pebbles do 40 ft.
2527 Gravel. do 43 ft. 6 in.
At 45 feet from the bottom of the river, from which level all the preceding depths were measured, the rounded stones were found from 6 to 12 inches in diameter, showing it to be a diluvial deposit.

## *Eocene Tertiary.*

62—68 Clay of various colors, Gay Head, Martha's Vineyard.
69 and 70 Sand agglutinated, yellow do
71 do white, do
72 do green, do
73 do with clay, do
74, 75, and 76 Lignite, do
77 Quartzose Conglomerate—cemented by iron, Gay Head.
78 and 79 do Cement argillo bituminous, do
80 Specimen of Oolitic aspect. do
81 Indurated Clay, do
82, 83, and 84 Impressions of Leaves on argillaceous iron ore, Gay Head.
85 Impression of a Seed Vessel; Gay Head.
86 Vegetable Remains do
87 Cast of a Venus, do
88 Cast of a Tellina, do
89 Cast of a Turbo, do
91, 92, 93, and 94 Concretions, do
95 Concretions in ferruginous sand, Nantucket.
26 Fossil Zoophyta ? in conglomerate, Gay Head, Martha's Vineyard.
97, 98, 99 Fossil Crabs in green sand, do
100, 101, and 102 Shark's teeth in green sand and conglomerate, Gay Head.
103 Crocodiles' tooth ? changed into flint, Gay Head.
104-108 Vertebrae (104 and 107 mineralized,) do
109 Fragment of a rib, do
110 and 111 Fragments of a bone, do
112 do with lignite in quartzose conglomerate, do
113, 114, and 115 do in do Gay Head.
116 do perforated do
117 and 118 Radiated Pyrites, do
119 Hydrate of Iron, pisiform, do
120 do mammillary, do
121 do nodular, perforated by lignite, do
122 and 123 do nodular, perforated by lignite, do
124 125, and 126 do columnar,
127 to 130 do compact and slaty, do
131 Selenite in clay with lignite, do
1706 White Clay, Kingston,
1707 Ferruginous Conglomerate, Marshfield.
1708 Concretion in Green Sand, do

1709 to 1711 Fossil Shells, Gay Head.
1712 to 1714 do Marshfield, Green Sand.
1715 to 1718 Lignite, Gay Head.
1719 Ferruginous Conglomerate, do
1720 Brown Sand, do
1721 Sand from decomposed Granite, do
1722 Green Sand do
1723 to 1731 Clays of various colors, do

## *New Red Sandstone.*

132 Conglomerate, coarse, Greenfield.
133 and 134 do variegated, Deerfield.
135 do of comminuted granite, Bernardston.
136 do do Westfield.
137 do from the ruins of argillo-micaceous slate, Greenfield.
138 and 139 do do Bernardston.
140 do from mica slate, talcose slate, granite, &c. Mount Toby.
141 do do Mouth of Miller's river.
142 do do epidotic do
143 Nodule from same conglomerate, do
144 Conglomerate from the ruins of Granite, South Hadley Canal.
145 do do Mt. Holyoke.
146 do do Belchertown.
147 do do Amherst.
148 do With a ferruginous concretion, South Hadley Canal.
149 do chiefly a nodule of Granite, Amherst.
150 do gray, Turner's Falls.
151, 152, 153 Tufaceous Conglomerate, Mt. Tom, Northampton.
285 do do
154 Coarse red sandstone, (Hoyt's Quarry,) Deerfield.
155 do Westfield.
156 do Whately.
157 do water worn. Greenfield.
158 do do
159, 160 Reddish Sandstone, W. Springfield.
161 Gray, do (Hoyt's Quarry,) Deerfield.
162 Reddish do Westfield.
163 do do Longmeadow.
164 do with pieces of fine red micaceous sandstone partially imbedded, Turner's Falls.
165 Fine Red do (smoothed,) Longmeadow.
166 do do do
167 Coarse Gray do from the Adit, Southampton Lead mines.
168 Light Gray do Mount Holyoke.
169 Darker do Turner's Falls.
170 Variegated do and sub-crystaline in contact with Trap, Titan's Pier, South Hadley.
171 Gray, fine do West Springfield.
172 do do Amherst.
173 Coarser do Turner's Falls.
174 Brecciated do near do
175 Micaceous, gray do South Hadley.
176 do under the trap, Mt. Holyoke.
177 Micaceous Sandstone, near trap, Mt. Tom.
178, 179 do do Turner's Falls.
180 do do under the trap, Mount Tom.
181 Amygdaloidal do near the trap, do
182 Amygdaloidal Sandstone, Granby.
286 do Northampton.
183 Micaceous do passing into shale, S. Hadley.
184 do do Sunderland Cave.
185, 186 Nodules of concretionary carbonate of Lime from micaceous sandstone, do
187 Micaceous Sandstone with carbonate of Copper, Turner's Falls.
188 Variegated do Agawam river, West Springfield.
189 do do Turner's falls.
190 do do South Hadley Falls.
191, 192 Red shale, slightly micaceous, jointed, near Turner's Falls.
193 Reddish fine micaceous sandstone, under the trap, Titan's Pier.
194, 195 do above shale, Turner's Falls.
196, 197, 198 do do South Hadley Canal.
199 Shale breaking into wedge-form masses, Turner's Falls.
200 do gray, hard, micaceous, do
201 do yellow decomposing, (a bowlder,) Amherst.
202, 203 do black, South Hadley Canal.
204 do do West Springfield.
205, 206, 207 Bituminous Marlite, do
208 do Sunderland.
209 do variegated, West Springfield.
210 do glazed, do
211, 212 Fetid Limestone, Paine's Quarry, do
213 do very hard and brittle, do do
214 do do do
215 do Meacham's Quarry, do
216 Argillo-ferruginous Limestone, Agawam River, do
217, 218, 219 Tripoli, Paine's Quarry, do
220, 221 do South Hadley Falls, on the W. Springfield shore.
222 to 225 Septaria or Ludus Helmontii, West Springfield.
226, 227 Concreted Carbonate of Lime, Mount Toby, Leverett.
228 do Sunderland Cave.
229 do Paine's Quarry, W. Springfield.
230 do stalactical, Sunderland Cave.
231 Calcareous Spar in Veins in black shale, W. Springfield.
232, 233, 234 Satin Spar in red and black shale, do
235 Sulphate of Baryta, below Turner's Falls, Greenfield.
236 Sulphate of Strontia on fetid carbonate of Lime, Meacham's Quarry W. Springfield
237 Bituminous Coal in bituminous marlite, W. Springfield.
238 do do with blende, do
239 Blende and Galena in fetid limestone, do

240 Carbonate of Iron in lenticular crystals Turner's Falls.
241 do ? South Hadley Canal
242 Iron Sand, Turner's Falls
243 Vitreous Copper in Sandstone, Simsbury Mines, Granby, Ct.
244 Pyritous Copper in Sandstone, Turner's Falls.
245 Green Carbonate of Copper, (poor specimen) Greenfield.
246 Bituminous Coal in sandstone, South Hadley, north part
247 do do South Hadley Canal
248 Anasphaltic Coal, do Turner's Falls.
249 Incrustation of purple fluate of lime on fetid Limestone, Paine's Quarry, W. Springfield.
250 to 254 Vegetable Remains on bituminous shale, Sunderland, north part.
255 do W. Springfield
256 do Sunderland.
257, 258 Vegetable (?) Relics in new red sandstone, Deerfield.
259 do do Greenfield.
260, 261 do do Deerfield
262, 263 Encrinite (?) shale, W. Springfield
264, 265 Ripple Marks and Concretions on shale, (See Fig. 100 ) do
266 do without reticulations, do
267 Zoophyta (?) converted into chert in shale, do
268 to 277 Concretions in fetid Limestone, W. Springfield.
278, 279 Icthyolites (*Eurynotus tenuiceps, Agas.*) in bituminous shale, Sunderland.
280 do two fish in contact, do
281 do only scattered fragments of the fish, do
282 Concretion in shale, Turner's Falls.
283 Moulds of Organic Relics (?) South Hadley Canal.
284 Veins of Clay, do
285, 286 (See the numbers following 153 and 182.)
1732 Conglomerate, gray, Amherst bowlder.
1733, 1734 do variegated, Southwick.
1735 do do Westfield, W. part.
1736 Reddish Sandstone, do. do.
1737 do. variegated, do. do.
1738 Conglomerate, Belchertown, bowlder.
1739 do. Granby.
1740, 1741 Red Sandstone, Wilbraham.
1742 do striped, Springfield.
1743 Dark compact sandstone passing into trap, Mount Holyoke.
1744 Black Shale, Montague.
1745 Gray Sandstone, Agawam River.
1746 Lenticular crystals of Calcareous Spar on limestone, Paine's Quarry, W. Springfield.
1747 Striped Sandstone, Rocky Hill, Hartford, Ct
1748 do hardened by trap. do
1749 Gray do do do
1750 Arragonite ? on Sandstone, Wilbraham.
1751, 1752, 1753, Vegetable relics on sandstone, Wilbraham.
1754 Striped Sandstone, Agawam River.
1755 Micaceous do do
1756 Vesicular do West Springfield.
1757 Compact fetid limestone, Chicopee Falls, Springfield.
1758 do Agawam River.
1759 do argillaceous do
1760 Septaria do
1761 do branching, Chicopee Falls.
1762 do kidney shaped, Agawam River.
1763 do Cabotville.
1764 do Chicopee Falls.
1765 do small in Shale, Agawam River.
1766 Bituminous Coal in Shale, Mitineaque Falls, W. Springfield.
1767, 1768, do with Calc Spar. do
2500 Decomposing Shale, Montague.
1769 Reddish Satin Spar, W. Springfield in red shale.
1770 White do. same place.
1771 Dicotyledonous Vegetable Remains with fossil fish on Shale, Sunderland
1772 do on do Northampton.
1773 Stem of plant on Shale, Chicopee Falls, Springfield.
1774 Fragments of vegetables, South Hadley, north part.
1775 Vegetable Relics on red shale, (See Plate 28, fig. 3) Wethersfield, Ct.
1776 Large vegetable Stems on Shale, Sunderland.
1777 Vegetable Relics and perhaps Echini Wethersfield, Ct.
1778 Vegetable Remains, S. Hadley Canal (See Plate 28, fig 5.)
1779 do Amherst, Bowlder.
1780 Fucoid, Suffield Ct. (See fig. 92 )
1781 Vegetable Stem converted into copper ore, Suffield Ct.
1782 do with fossil footmarks, Chicopee Falls, Springfield, (See Fig. 89.)
1783, 1784 Unknown vegetable relic on Shale, Northampton.
1783 do Wethersfield, Ct.
1784, 1785 Clay Veins in black shale with vegetable relics, Cabotville
1786 Clay Veins in relief, S. Hadley.
1787 Unknown Relic, (See fig. 93.) Chicopee Falls
1788 do Wilbraham.
1789 do Sunderland, (fig. 94.)
1790 do Wethersfield, Ct.
1791 Micaceous Sandstone with concretions, S. Hadley.

1792 Unknown animal relic (fig. 98,) Wethersfield.
1793 do ? Montague, S. W. part.
1794 Slab of fossil fishes, genus Eurynotus of Agassiz.
1795 Animal ? relic, (See Fig. 99,) Sunderland.
1796 Ornithoidichnites tuberosus in relief, Turner's Falls, Montague.
1797 do in relief, small, Wethersfield Ct.
1798 do divaricatus, Cabotville.
1799 do Deanii, two tracks, Wethersfield.
1800 do do and tenuis, do
2528 do gracilior and minimus several tracks, Wethersfield.
2529 do tetradactylus, in relief near Cabotville.
2530 Sauroidichnites Emmonsii ? several tracks, Wethersfield.
2531 S. minitans, do
2532 do do several tracks in relief, Chicopee Falls.
2533 S. polemarchius, do
2534 Ornithoidichnites elegans, Montague.
2535 do elegantior, do
2536 do macrodactylus, elegans, and minitans, Wethersfield
2537, 2538 Sauroidichnites Emmonsii, Wethersfield.
2539 Ornithoidichnites isodactylus, Horse Race, Gill.
2540 do minimus, two tracks one of them distorted, Wethersfield.
2541, 2542 Gray Sandstone, S. Hadley, at the Artesian Well.
2543 Soft striped shale, Rail Road Cut, W. Springfield, W. part.
2544 Water Limestone, Agawam river, W. Springfield.
2545 Ripple Marks, Horse Race, Gill.
2546 do Wethersfield.
2547 do (See Fig. 88.) do
2548 do finer do
2549 do very small do
2550 Impressions of Rain Drops, do
2551 do less distinct, do
2552 do much enlarged, do
2553 do much more spread, do
2554 do with fine ripple marks, do
2555 Partial Concretion ? do
2556 do ? do
2557 Ornithoidichnites giganteus in relief on stone, Northampton.
2558 Plaster Cast of do. showing the claws distinctly, from Wethersfield.
2559 do of O. ingens from Gill.
2560 Plaster Mould of Sauroidichnites polemarchius.
2561 do of O. tuberosus.
2562 Plaster Cast of O. tuberosus.
2563 Plaster Mould of O. tuberosus.
2564 do of O. Expansus.
2565 Plaster Cast of 4 tracks of O. cuneatus from S. Hadley.
2566 do of O. parvulus.
2567 do of S. Barratii.
2568 Plaster Mould of S. Jacksoni.
2269 do of S. heteroclitus.
2570 do of S. tenuissimus.
2571 do of S. Baileyi.
2572 Plaster Cast of a double track of S. Emmonsii ?
2573 do of S. palmatus.
2574 Plaster Mould of S. longipes.
2575, 2576 do track of S. Emmonsii at different depths.
2577 do of small slab of tracks.
2579 do of O. macrodactylus.
2579, 2580 do of O. elegans.
2581 to 2584 Plaster Cast of O. Deanii.
2585 do of O. tetradactylus.
2586 do of O. graciiis.
2587 do of O. isodactylus.
2588 do of O. delicatulus.
2589 do of two tracks of O. minimus.

## *Graywacke*

287 Conglomerate, the variety most common, Dorchester.
288 do do Swansey.
289 do do with a vein of quartz, Brookline.
290 do do Attleborough.
291 do do reddish, Roxbury.
307 do red, (Old red sandstone,) } Attleborough.
292 do gray, } Natick.
293 do nodules chiefly mica slate, Bradford.
294 do nodules fine mica slate or quartz rock, containing mag. ox. iron, Middletown, R. Island.
295 do quartzose brecciated, Attleborough.
296 Breccia, fragments of slate reunited, Natick.
297 do do Randolph.
298 do fine, do Natick.
301 do somewhat rounded, do slaty, Dorchester.
302 do do do Canton.
307 see No. following 291.
309 Old red Sandstone, red from red oxide of iron, Attleborough.
311 do do Wrentham.
312 do Chocolate color, Rehoboth.
313 do do Walpole.
314 do do Abington.
315 do do Canton.
316 do do slaty, Wrentham.
318 do do with veins of white quartz, Wrentham.
319 do red, Greenbush, N. York.
324 Classical graywacke, gray, Rehoboth.
325 do reddish, (Old Red Sandstone,) do

326 Graywacke red, Attleborough.
327 do do (bowlder) Hull
328 do gray, Newton.
329 do with veins of quartz, Pawtucket.
330 do with do Stephentown, N. Y.
331 do with do Attleborough.
332 do Rehoboth.
333 do with anthracite, Troy, N. Y.
334 do gray, Stephentown, N. Y.
335 Graywacke Slate, gray, Newton.
336 do do Watertown
337 do do Pawtucket.
338 do light, do Newbury.
339 do do glazed, Newport, R. Island.
340 do do Watertown
341 do do Natick.
342 do do epidotic, Newton.
343 do do Taunton.
344, 345 do deep red from oxide of iron, Attleborough.
346 do gray, do
347 do reddish, Newbury.
348 do do with quartz veins, Pawtucket.
349 do do divided by joints, Wrentham.
350 do do do Pawtucket.
351 do do variegated, Newbury.
352 do do Milton.
353 do red Newbury, Kents Island.
354 do reddish variegated, Hull.
355, 356 do gray, Nassau, N. Y.
357 Novaculite, Charlestown.
358 Argillaceous Slate, coal mine, Portsmouth,
359 do variegated, Charlestown.
360 do rhomboidal, Rainsford's Islands.
361 do do South Boston.
362 do laminæ curved, Rainsford Island.
363 do light gray, Halifax.
364 Argillaceous Slate with veins of calcareous spar, Watertown.
365 do variegated, Quincy.
366 do Hull.
367 do (Novaculite ?) Boston Light House.
368 do (do ?) Hingham.
369 do (do ?) Spring Street, Roxbury.
370 do (do ?) Watertown.
379 Wacke from a vein in granite—lead mine, Easton.
391 Prase with asbestus, Brighton.
393 Cubical Pyrites in anthracitous slate, Wrentham coal mine.
394 Asbestus in slate, Somerset.
395 Impressions of ferns &c. on slate, Newport, R. Island.
396 Sphænophyllum ? on anthracitous slate do
397 Unknown impressions on do do
398 Calamites, Wrentham, Coal Mine.
399 Neuropteris ? &c. on slate, do
400 Relic on hard schistose rock, Attleborough.
401 Anthracite, Wrentham.
402 do Portsmouth, R. Island.
403 See the No. following No. 803.

1801 Conglom. nodules mostly quartz, Berkley.
1802 do do Dighton.
1803 do calcareous, Mansfield.
1804 do Roxbury.
1805 do pebbles chiefly quartz, Attleborough.
1806 Old Red Sandstone ? Conglomerate, Attleborough, S. W. part.
1807 Conglomerate, Walpole.
1808 Old Red Sandstone Conglomerate, Attleborough S. W. part.
1809 do do do
1810 Conglomerate (bowlder) Hancock.
1811 Old Red Sandstone Conglomerate, Wrentham, S. W. part.
1813 Conglomerate, Newton W. part.
1814 do Fall River.
1815 do fine (bowlder) Hancock W. part.
1816 do Swansey.
1817 do Walpole.
1820 Slaty, reddish, Roxbury.
1821 do with veins of quartz, Attleborough.
1822 do wedged between masses of sienite. Middleborough.
1823 do chiefly slaty compact feldspar. Plympton.
1824 do Coal Measures, Mansfield.
1825 do Old Red Sandstone, Attleborough.
1826 do do Wrentham.
1828 do gray, (bowlder) Rochester.
1829 Graywacke, gray, Hanover Four Corners.
1831 Slaty do (bowlder.) Middleborough.
1835 Graywacke with veins of amianthus, Dorchester.
1836 Prase, coal mine, Cumberland, R. I.
1837 Petalite in Limestone, Attleborough.
1838 Calcareous Spar on graywacke, Mansfield.
1839 Graywacke with anthracite, Abington.
1840 Shale, with organic relic, Cumberland, R.I.
1841 do Glazed, do
1842, 1843 Anthracite, do
1844 Shale glazed, Mansfield.
1845 Anthracitous Shale, Hardon mine, Mansfield.
1846 Anthracite, do do
1847 do Wading Vein, do
1848 do Foxborough.
1866 Graywacke, Inscription Rock, Asonet, Berkley.
1910 Limestone, compact, Attleborough.
1911 do with Slate, do
2499 Glazed Shale, Mansfield.
2591 Calamites, cylindrical, Wrentham.
2592 to 2594 do flattened, do
2595 Stigmaria, with depression on one side, do
2596 do with central axis, Mansfield.
2597 Monocotyledonous Plant ? on shale, Mansfield, Hardon Mine: shows the lower part of the leaf.
2598 do Upper part of leaf. do
2599 do central part of do do

2600 Flattened Stem, pointed, Wrentham South part.
2601 Large Fern, (Plate 23,) Mansfield.
2602 Neuropteris, Wrentham.
2603 Sphenopteris, Hardon Mine, Mansfield.
2604 Neuropteris, do do
2605 Fern, do do
2606 Pachypteris ? or Odontopteris ? do do
2607 Small Reeds, Wrentham.
2608 do and Sphænophyllum, Hardon Mine, Mansfield.
2609 Pecopteris and Sphænophyllum emarginatum ? Mansfield.
2610 Sphenopteris.
2611 Asterophyllites ? &c. Mansfield.
2612 Annularia, do
2613 Asterophyllites or Equisetum, Mansfield.

## *Metamorphic Slates.*

299 Conglomerate, fragments of compact feldspar, cement indurated clay, Saugus.
300 Breccia, fragments of compact feldspar united, Nantasket Beach.
303, 304 Slaty aggregate of quartz and mica, Middletown, R. Island.
305, 306 do with argillaceous matter, Fall River.
308 do passing into mica slate, do
317 Talcose (?) Slate, Randolph
320 Talcose aggregate conglomerated, Canton.
321 do Cambridge.
322 do Walpole.
323 do Newbury.
371 Amphibolic Aggregate, Middletown, R. I.
372 Varioloid Wacke, Saugus.
373 do Brighton.
374 do Hingham.
375 do Nantasket Beach.
376 do Hingham.
377 do nodules quartz and epidote, Brighton.
378 do approaching porphyry, Needham.
380 Amygdaloid passing into siliceous slate, Newport, R. I.
381 Siliceous Slate, porphyritic, Newport.
382 do do
383 do with veins of granite do
384, 385 do Nahant.
386 Passing into chert, do
387 Jasper, Newport, R. I.
387 1-2 Heliotrope ? do
388 Clouded Jasper (Compact feldspar ?) Saugus.
1060, 1061 Metamorphic Slates, Duxbury.
388, 389 Jasper, or red compact feldspar Saugus.
392 Zoisite, in Amphibolic Aggregate, Middletown, R. I.
1812 Breccia, fragments porphyry, Nantasket Beach.
1818, 1819, Metamorphic Graywacke Slate passing into trap, Kent's Island, Newbury.
1827 Quartzose reddish Slate, do
1830 Talcose Slate, quartz in grains, Wrentham, S. part.
1832 Slaty porphyry, somewhat mechanical, S Natick.
1833 Varioloid Wacke, do
1834 do Hingham.
1849, 1850, 1851, 1852, Conglomerated Clay Slate, Slate Quarry, Harvard.
1853, 1854, 1855 Conglomerated Mica Slate, Bellingham.
1856 Mica Slate associated with the last three Nos Bellingham
1857 Junction of the Mica Slate and Conglomerate, do
1858 Spangled Mica Slate associated with the Conglomerate, Bellingham.
1859, 1860 Talcose Slate associated with the Conglomerate, Bellingham.
1861 Conglomerated M Slate, Wickford, R. I.
1862 Mica Slate associated with Conglomerate, Wrentham, S. part.
1863 Bastard Mica Slate, Brecciated, Wrentham.
1864, 1865, Aggregate of mica and quartz, Fall River.
1867, 1868 Metamorphic Rock, Head of Nantasket Beach.
1869 do Duxbury.
1870 Graywacke Slate passing into Hornstone, Weston, N. part.
1871, 1872 Hornstone with a slaty structure, do
2105, 2106, 2107, 2108, Mica Slate (whetstone slate,) Bellingham, N. E. part.
823 Mica Slate, Whetstone quarry, Smithfield, R. Island.

## *Argillaceous Slate.*

404 Macle in argillaceous slate, (bowlder) Worcester.
405 Common argillaceous slate, Guilford, Vt.
406 do Lancaster.
407 do Shirley.
408 do Harvard.
409 do Pepperell.
410 do passing into mica slate, Bernardston.
411 and 412 do with quartz veins, Guilford, Vt.
413 do wavy surface, Glen, Leyden.
414 and 415 do contorted, Guilford.
416 Micaceo-argillaceous slate *in echellon*, Glen Leyden.
417 Argillaceous Slate much bent, Guilford, Vt.
418 do do do
419 do exhibiting a double flexure, do
420 do red, Sand Lake, N. Y.
421 do gray beneath limestone, Chatham, N.Y.
422 do epidotic, Hancock.
423 Chlorite Slate, Guilford, Vt.
424 & 425 passing into Novaculite, Guilford, Vt.
426 Chiastolite in argillaceous Slate, Lancaster.
427 A card of Macles. do

1893 Clay Slate, Harvard, Quarry.
1894, 1895, do jointed, Lancaster.
1896 do Harvard, with a vein of granite.
1897, 1898, do Groton.

## *Limestone.*

428 and 429, White Marble, polished, Adams.
430 and 431 do do W. Stockbridge.
432 do do Lanesborough.
433 and 434 do do New Ashford.
435 White Saccharine Limestone (bowlder,) Peru.
436 Granular white Dolomite, Sheffield.
437 Gray Marble, (polished.) Lanesborough.
438 do do W. Stockbridge.
439 and 440 Gray Marble, clouded (polished.) New Ashford.
441 do do do W. Stockbridge.
442 Dove colored Marble, clouded (polished.) Great Barrington.
443 Gray Limestone, Sheffield.
444 do Lee.
445 do nearly compact, Lanesborough.
446 do do W. Stockbridge.
447 do light, Pittsfield.
448 Dark gray limestone nearly compact, Williamstown.
449 and 450 do do Stephentown, N. Y.
451 do Canaan, N. Y.
452 do compact with veins of calc. spar, Chatham, N. Y.
453 do with numerous veins of quartz, do
454 Yellowish coarse Limestone with a foreign mineral, Stockbridge.
455 Micaceous limestone, do
456 do with mica and quartz, Canaan, Ct.
457 do do Lanesborough.
458 do do South Lee.
459 do do Whately.
460 do do Colrain.
461 do do Conway.
462 do do Heath.
463 do do Southampton.
464 do with veins of quartz and calc. spar, Conway.
465 do with veins of granite, Colrain.
466 do with veins of argentine, W. Hampton.
467 do decomposed at the surface, Guilford, Vt.
468 and 469 Gray Limestone in mica slate (bowlders.) Williamsburgh.
470 and 471 Fossiliferous Limestone, Bernardston.
472 do brecciated (polished.) do
473, 474 and 475 Disintegrating Organic Remains, in do do
476 Coarse white limestone with graphite (bowlder.) Blanford.
477 and 478 do Whitingham, Vt.
479 do Whitingham, Vt.
480 do micaceous, do.
481 do with chlorite (a bowlder, Conway,) originally from Whitingham, Vt.
482, 483 Dolomitic (?) Limestone, Somerset, Vt.
484 Fine Granular Dolomite, do
485 White crystaline fetid limestone, Bolton.
486 Petalite, do
487 and 488 Limestone Magnesian, Boxboro'.
489 do with serpentine, Littleton.
490 do do
491 and 492 Coarse granular whitish Limestone. Chelmsford.
493 do do Acton.
494 Gray do Walpole.
495 Compact light gray do Newport, R. I.
496 Compact white translucent Marble (polished.) Stoneham.
497 Granular clouded limestone, Smithfield, R. Island.
498 White do Harris Rock, do
499 do do Dexter Rock, do
500 Flesh colored do do
501 Flexible Marble Slab, New Ashford.
502 Laminated Calcareous Spar, Bernardston.
503 Crystalized do do
504 Hydrate of Iron, do
505 Magnetic Oxide of Iron, do
506 Nephrite, Stoneham.
507 Allochroite? do
508 Specks of Serpentine in limestone, Boxborough.
509 Crystaline augite in calc. spar, do
510 Calc. Spar, wine yellow, in limestone, do
511 Actynolite, in do do
512 do radiated in do do
513 Compact purple scapolite &c. do
514 Lilac do Bolton.
515 Crystalized do in gray quartz, do
516 Dark gray do (Nuttallite) do
517 Sahlite, do
518 do with compact scapolite, Acton.
519 Diopside, Whitingham, Vt.
520 Actynolite, Chelmsford.
521 and 522 Bisilicate of Magnesia, (Boltonite.) Bolton.
523 and 524 White amianthus, Chelmsford.
525 Limestone and white talc, Smithfield, R. I.
526 Crystaline augite, scapolite, and cinnamon stone, Carlisle.
527 Cinnamon Stone and pargasite, do
528 do do
529 Crystalized Scapolite, Littleton.
530 Actynolite do
531 Phosphate of Lime in scapolite, Littleton.
532 Sphene with scapolite and petalite, Bolton.
533 do do Littleton.
534 do with augite and scapolite, Carlisle.
535 White crystalized Augite in dolomite, Canaan, Ct.
536 Carbonate of Lime and Augite, Lee.
537 Tremolite in dolomite, do
538 do do Canaan, Ct.

539 Tremolite in dolomite, Sheffield.
540 Bisilicate of Lime and (Scapolite Rock.) Trisilicate of Alumina, Canaan, Ct.
541 do compact (the common variety.) do.
542 do with dolomite, do
543 do with mica passing into mica slate, do
544 do with quartz and augite, do
1899, 1900 Limestone, common carbonate, marble, North Adams.
1901, 1902 do do do Fitch's Quarry, West Stockbridge.
1903 do do do W. Stockbridge.
1904 do do do Sheffield.
1905 do do do Lanesborough.
1906 do do do Egremont.
1907 do do do Girard College Quarry, Sheffield.
1908, 1909 do common, Boston Corner.
1912 Sparry Limestone, Lanesborough.
1913 do New Ashford.
1914 Black Limestone, Lanesborough.
1915 do bowlder, Richmond.
1916 Gray do Hancock.
1917 Reddish do S. Williamstown.
1918 Gray do Concord.
1919 do do Whately.
1920 1921 do do Ashfield.
2503 do do Norwich.
1922 do do bowlder, Royalston.
1923 do do compact, Copake, N. Y.
1924 Dolomite, Tyringham, S. Part.
1925 do marble, Sheffield.
1926, 1927 do Smith's Quarry, New Marlborough.
1928 do Hadsell's Quarry, do
1929 do near S. M. House, do
1930 do S. of College, Williamstown.
1931 do Tyringham, N. W. Part.
1932 do clouded marble, Gr. Barrington.
1933 do Hadsell's Quarry, New Marlborough.
1934 do Lanesborough, E. Part.
1935 do N. W. base of Saddle Mt. Williamstown.
1936, 1937 do Quarry, 1 m. W. of village, Lee.
1938 do near M. House. Dalton.
1939 do East Bed, Middlefield.
1940, 1941 do Cole's Brook, do
1942 do Becket, S. E. Part.
1943 do do farther South.
1944 do bowlder, Sherburne.
1945 do do Bradford, E. Part.
1946 do near the Rail Road, Natick.
1947 do near center, do
1948 do Rail Road cut, do
1949, 1950, 1951 Compact yellow Limestone, dolomitic, Rail Road Cut, Natick.
1952 Compact white do dolomitic, Stoneham.
1953 Variegated Marble, E. quarry, Middlefield.
1954, 1955 Verd Antique, do do
1956 Gray Limestone Slaty, Copake, N. Y.
1957 do Lanesborough
1958 do West Stockbridge.
1959 Gray Limestone, Smith's quarry, N Marlborough.
1960 Micaceous Limestone, Cheshire.
1961 Limestone with yellow mica, Middlefield, E. quarry.
1962 Junction of marble and mica slate, Fitch's quarry, West Stockbridge.
1963 White micaceous limestone, Middlefield, E. quarry.
1964 Talcose Limestone, Becket.
1965 Micaceous do gray; Middlefield, E. quarry.
1966 Junction of limestone and talco-micaceous slate, Saddle Mt. Williamstown.
1967 Calcareous Mica Slate, Saddle Mt. E. Bridge, Adams.
1968 Carbonate of lime mica and quartz, West Stockbridge.
1969 do and quartz, do
1970 Dolomite and feldspar, Tyringham S part.
1971 do with mica, quartz, &c. S. Lee.
1972 Limestone and augite, N. Marlborough, E. of M. House.
1973 Micaceous Limestone, decomposed, Pepperell.
1974 Dolomite with white augite, Tyringham.
1975 do with tremolite, Becket, S. E. part.
1976, 1977 do do Lee.
1978 Stalactite from cave, Lanesborough.
1979 Carbonate of Iron, Newbury.
1980 Tremolite (?) in limestone, Lenox.
1981 Sphene in talcose limestone, Becket.
1982 do do Adams.
1983 Feldspar and quartz: a vein in limestone, Cole's brook, Middlefield.
1984 Galena in limestone, gangue quartz, Alford.
1985 do and pyrites, do
1986 Crystalized Quartz in limestone, South Williamstown.
1988 Carbonate of Iron, Newbury.
2646 Slab of clouded flexible marble, Great Barrington.

### *Quartz Rock.*

545 White hyaline Quartz from mica slate, Heath.
546 do do Plainfield.
547 Whitish Quartz nearly opaque do Saddle Mountain.
548 do do from a vein in hornblende slate, Gill.
549 do containing argillaceous slate, Guilford, Vt.
550 Fine white granular Quartz, Cumberland, R. Island.
551 Reddish granular do Berkshire County.
552 do do Cheshire.
553 and 554 do Pittsfield.
555 Dark Gray do Windsor.
556, 557 and 558 Arenaceous disintegrating Quartz, Cheshire.
559 Granular Quartz, striped, Conway.
560 Hyaline dark smoky Quartz, Amherst.

561 Smoky Quartz in argillaceous slate, Guilford, Vt.
562 do light smoky, do Sterling.
563 Reddish compact Quartz, Leverett.
564 do do Prescott.
565 Bluish compact quartz, Amherst.
566 Greenish do Cumberland, R. I.
567 Porous Quartz (Buhrstone) Washington.
568 Arenaceous Quartz with actynolite, associated with gneiss, Pelham.
569 Gray fine granular quartz, Cumberland, R. I.
570 do do Framingham.
571 Gray hyaline or coarsely granular quartz with feldspar. Pelham.
572 Light gray granular Quartz with small scales of mica. Lee.
573 do do stratified (Buhrstone locality) Pittsfield.
574 The same with more mica and contorted folia, Lee.
575 Gray hyaline quartz with mica; associated with gneiss, New Salem.
576 Brecciated particolored quartz with mica, Amherst.
577 Rhomboidal quartz with mica, Northfield.
578, 579 and 580 Compact gray quartz with mica, Bernardston.
581 Quartz and talc, Webster.
582 and 583 do Hawley.
584 Quartz with Actynolite connected with gneiss, Pelham
585 do with crystals of hornblende, Hawley.
586 Argillaceous slate with quartz veins, S. Hadley Canal.
587 Quartz granular and mica connected with gneiss, Windsor.
588 do Webster.
589 do associated with gneiss, Mendon.
590 do Webster.
591 do under the Burhstone, Washington.
592 do Dalton.
593 Quartz mica and feldspar passing into gneiss, Bernardston.
594 Quartz and mica, Framingham.
595 do Cumberland, R. Island.
596 do passing into mica slate, Zoar at the Bridge.
597 Arenaceous quartz and mica, Plainfield.
598 Quartz and mica, vesicular, Chesterfield.
599 do Conway.
600 Quartz mica and feldspar passing into gneiss, Mendon.
601 Quartz with argillaceous slate near the lime bed, Bernardston.
602 Brecciated Quartz, Leverett.
603 do Amherst.
604, 605 and 606 do cement hematitic iron, Dalton.
607 do cement iron, Amherst.
608 do quartz and micaceous slate, Williamsburgh.
609 Quartzose Conglomerate (bowlder.) cement mica slate, Windsor.
610 do do Adams.
611 Quartz with disseminated iron pyrites, Windsor.
612 do ferruginous, bowlder, Worthington.
613 do passing into yellow jasper, Chesterfield.
1989 Quartz, crystaline, Wendell.
1990 do Vein in Rail Road, Roxbury.
1991 do agatized, North Rochester.
1992 do do Middleborough.
1993 do Athol.
1994 do Granby, E. part.
1995 do granular, Uxbridge.
1996 do arenaceous, Dalton.
1997 do gray, Williamstown.
1998 do arenaceous, Washington.
1999 do top Monument Mt.
2000 do Mt. east part of Williamstown.
2001 do red, bowlders, Franklin.
2002 do rhomboidal, Alum Hill, Sheffield.
2003 do Bald Mt. N. Adams.
2004 do Natick.
2005 Quartz and Mica (firestone ?) Douglass, E. part.
2006 do and Hornblende, Warwick.
2007 do do rhomboidal, Leverett.
2008 do Firestone, Tyringham, N. part.
2009 do rhomboidal, New Marborough; Umpachena Falls.
2010 do Firestone, Washington.
2011 do slaty, Alum Hill, Sheffield.
2012 do with veins of iron ore, Montague, mouth of Miller's River.
2013 Quartz and mica, Palmer.
2014 do do contorted, Zoar.
2015 do do Beartown Mt. near top.
2016 do do Saddle Mt. E. Ridge.
2017 do do and feldspar near Hop Brook, Tyringham.
2018 do do Bald Mt. N. Adams.
2019 do do Rail Road Cut, Monson.
2020 do do Beartown Mountain.
2021 do do Palmer.
2022 do do Millville, Mendon.
2023 do do arenaceous, Williamstown. South of College.
2024 do do South Mt. Northfield.
2025 do do Rail Road Cut, Monson.
2026 do do Washington, W. part.
2027 do do and feldspar, Beartown Mt. top.
2028 do do overlying metamorphic slate, Bellingham, N. E. part.
2029 do do and feldspar, Beartown Mt.
2030 do do conglomeritic, Washington, W. part.
2031 do do do do
2032, 2033, 2034, Quartzose Breccia, Washington, W. part, a bowlder, cement hematite.
2035 do containing schorl, E. foot of Monument Mt. Great Barrington.
2036 do with do Warwick.

2037 Quartz with argentiferous galena, Uxbridge, S. part.
2038 do with carb of copper, Williamstown.
2039 do with chlorite, bowlder, Middleborough S. part.
2040 Quartz Rock ? decomposing, Williamstown, S. of College.
2041 Quartz and mica, Millville, Mendon.
2042 Jasper, rolled pebble, N. Adams.
2043 Quartz, compact, mouth of Miller's river. Montague.
2044 do firestone, Pelham, W. part.
2045 do do with actynolite, do.

## Mica Slate.

614 Mica Slate, common, quartz laminar, mica scaly shining, Colrain.
615 do do do do Peru.
616 do do do do Blanford.
617 do do do do Smithfield, R.I
618 do do do do Shelburne.
619 do do do do Florida.
620 do do do do Framingham.
621 do do do do Cheshire.
622, 623 do of a fibrous aspect, Northfield.
624 do do do W. Stockbridge
625 do very even and shining, Bolton, Ct.
626 do layers tortuous, quartz tuberculous, Stockbridge.
627 do feldspar and quartz tuberculous passing to gneiss, Pittsfield.
628 do with feldspar passing to gneiss, mica shining, Colrain.
629 do do do Westfield.
630 do do do Leverett.
631 do do do Montague.
632 do do do Granville.
633 do do do do
634 do do do Florida.
635 do do do Ware.
636 do do do Wachusett, Princeton.
637 do do do Enfield.
638 to 641, See under Talcose Slate.
642 do amphibolic and garnetiferous, Norwich.
643 do with phosphate of lime, Conway.
644 do do Colrain.
645 do garnetiferous, Chesterfield.
646 do staurotidiferous, do
647 do spangled, Goshen.
648 do do Plainfield.
649 do do jointed, do
650 do do Norwich.
651 Argillo-micaceous Slate, Goshen.
652 do jointed, Greenfield.
653 do rhomboidal, do
654 do Charlemont.
655 do Hawley.
656 do Heath.
657 do Lanesborough.
658 do glazed, with quartz, Glen, Leyden.
659 Argillo-micaceous slate, controted, Guilford, Vt.
660 do Hancock.
661 do with undulating surface, Bradford.
662 do contorted, with layers of quartz, Guilford, Vt.
663 do do Whately.
664 do do Guilford, Vt.
665 do do Bernardston.
666 Argillo-micaceous slate, contorted, with layers of quarrz, Williamstown.
667 do Saddle Mountain.
668 Arenaceous Mica Slate, Norwich.
669 do passing into gneiss, Bolton.
670 do mostly quartz, argentine locality, West Hampton.
671 do Norwich.
672 do vesicular (see No. 598.) Chesterfield.
673 do Chester.
674 do Norwich.
675 Arenaceous Mica Slate, Woonsocket Falls, Cumberland, R. I.
676 do Chester.
677 do with feldspar, Enfield.
678 do Chester.
679, 680 do whetstone slate, Enfield.
681 do do Norwich.
682 do Sherburne.
683 do used for monuments, Halifax, Vt.
684 do Greenfield.
685 do jointed. Deerfield.
686 do do
687 Argillo-arenaceous Slate, reddish, at the junction with the new red sandstone, Glen, Leyden.
688, 689, 690, do bent, do
691 Arenaceous Mica Slate, Worcester.
692, 693 do anthracite locality, do
694 do with a talcose aspect, do
695, 696, 697 do do
698 do with veins of granite, Lunenburg.
699, 700 do mostly quartz, Groton.
701 Talco arenaceous slate, bowlder, Worcester.
702 Arenaceous Mica Slate, Dracut.
703 do passing into clay slate, Worcester.
704 do talcose, Lowell.
705 do Methuen.
706 do mostly quartz, Worcester.
707 do Andover Bridge.
708 do with veins of quartz, Worcester.
709 do S. Hampton, N. Hampshire.
710 do East Sudbury.
711 do Webster.
712 do Oxford.
713 Plumbaginous Mica Slate, contorted, Worcester.
714 do Ward.
715 do Amesbury.
716 Brecciated Mica Slate, do
717 Anthracitous Mica Slate, Dudley.
718, 719 do anthracite locality, Worcester.
720 Plumbaginous Mica Slate, Hawley.

721 Mica Slate, common, South Hampton.
722 Mica Slate, mica and quartz, laminar, Northfield, west of Ct. River.
723 do do Conway.
724 do conglomerated, passing into sienite, Whately.
725 Indurated mica slate, do
726, 727 Augite rock associated with mica slate, Williamsburg.
728 Phosphate of Lime in mica slate, Norwich.
729 Fluate of Lime, Westmoreland, N. H.
730 White milky quartz, Warwick.
731 Fetid hyaline quartz, Goshen.
732 Fetid quartz, crystalized, Williamsburg.
733, 734 Rose red quartz, Blanford.
735 do Chelmsford.
736 Yellow Hyaline Quartz, Colerain.
736 Blood red, Colerain.
737, 738, 739, 740, 741, 742, 743, 744, Quartzose breccia agates, Conway.
745 do Amherst.
746 Tabular or foliated quartz, Conway.
747 do with a pseudomorphous aspect, do.
748 Yellow Quartz, Amherst.
749 Fibrolite in Mica Slate, Lancaster.
750 Kyanite with phosphate of lime, Chesterfield.
751, 752 do do
753 do Chester.
754 Staurotide in mica slate, Chesterfield.
755, 756 Andalusite, crystalized, Westford.
757 Fibrous Talc? associated with andalusite, do
758 Schorl in quartz, Blanford.
759, 760 Garnets in mica slate, Chesterfield.
761 Crystalized Epidote in amphibolic mica slate, Goshen.
762 do do Williamsburgh.
763 Zoisite? with specular oxide of iron and carbonate of lime, Goshen.
764 do Chesterfield.
765 Idocrase, epidote, calcareous spar, &c. Worcester.
766 Anthophyllite in mica slate, Chesterfield,
767, 768 do Blanford.
769 Cummingtonite, quartz, and garnets, Warwick.
770 do Cummington.
771 Black mica, Westfield.
772 do Norwich.
773 Fibrous Talc? Blanford.
774 Anthracite from mica slate, (coal mine), Worcester.
775 Plumbago; or anthracite passing into Plumbago, Worcester.
1549 Amianthus, from the anthracite mine, do.
1550 Bucholzite? do.
776 Red oxide of iron from the vein of manganese, Conway.
777 Pyrolusite, do.
778 do with siliceous sinter, Amherst.
1027 Ore of Manganese, Hinsdale.
779 Micaceous Oxide of Iron, Montague.
780 Arsenical Iron, Worcester.
781 Crystalized Arsenical Sulphuret of Iron, do.
782 Massive, do do
783 Carbonate of Iron, do
784 do Sterling.
785 do with pyritous copper, do
786 Galena and blende, do
787 Reddish sulphuret of Zinc, do
788 Rutile, Conway.
818 Firestone, Stafford, Ct.
2046 Mica Slate passing into granite, Russell.
2047 do with white quartz, Heath.
2048 do Enfield.
2049 do black, Rail Road Cut, Monson.
2050 do chiefly Rail Road Cut, Auburn.
2051 do Rail Road Cut, near Clappville, Leicester.
2052 do Sodom, Rail Road Cut, Wilbraham.
2053 do Monroe.
2054 do Rail Road Cut, Sodom, Wilbraham.
2055 do Warwick.
2056, 2057 do Russell.
2058 do rhomboidal, Palmer, Quarry near the Meeting House.
2059 do Westminster, E. of center.
2060 do Erving.
2061 do S. Mt. Northfield.
2062 do Sodom Mount, Southwick.
2063 do interstratified with limestone, W. Stockbridge, E. part.
2064 do Lenox Mount, Lenox.
2065 do passing into gneiss, Granville.
2066 do between gneiss and quartz rock, Washington, W. part.
2067 do Norwich.
2068 do above limestone, Shaker Village, Tyringham.
2069 do Erving.
2070 do Warwick, east of center.
2071 do firestone, Warwick, south of, do.
2072 do do Enfield, south of center.
2073 do do Warwick.
2074 do do E of Meeting House.
2075 do Lenox Mountain, Lenox.
2076 do W. Stockbridge. See No. 2063.
2077 do passing into quartz rock, Northfield. S. E. part, South Mt.
2078 do Whetstone slate, Wendell.
2079 do Saddle Mt. east ridge.
2080 do do calcareous with iron pyrites, Adams.
2081 Talco-micaceous Slate, Boston corner.
2082 Mica Slate, Saddle Mt. Williamstown.
2083 do do N. W. part, do.
2084 do W. Stockbridge. See No. 2063.
2085 Argillo-micaceous slate, Egremont, W. part.
2086 do with native alum, Conway, N. part.
2087 Native alum from No. 2086.
2088 Mica Slate, (firestone?) Russell.

2089 Mica Slate, top of Wachusett.
2090 do Rutland, E. part.
2091 Talco-micaceous slate, Millville, Mendon.
2092 Mica Slate, Leominster, W. part.
2093 Argillo-micaceous slate, Williamstown, West of College.
2094 Mica Slate and limestone, over the marble, Lanesborough.
2095 do over limestone, N. Ashford.
2096 do over marble, do
2097 do Mt. Everett, Mt. Washington.
2098 do do east slope, do
2099 do Sheffield, W. of village.
2100 do Saddle Mt. Williamstown, colored by decomposing pyrites.
2101 do above limestone, Hudson Brook, North Adams.
2102 Talco-micaceous, with hornblende and iron pyrites, Monson.
2103 do with pyrites, do
2104 Mica Slate, Rail Road Cut, Monson.
2109, 2110 do Franklin.
2111 do Spicket Falls, Methuen.
2112 Augitic Mica Slate, Heath.
2113 do Sodom Mt. Southwick.
2114 Mica, hornblende and feldspar, apparently of igneous origin, in Mica Slate, Warwick.
2115 Porous Quartz, with oxide of iron in Mica Slate, Richmond.
2116 Mica Slate with garnets, south Mt. Northfield.
2117 do do do do
2118 do with staurotide and garnets, Auburn.
2119 do with garnets, Rail Road, Middlefield.
2120 Garnetiferous, do Rowe W. part.
2121 Mica slate, with staurotide and garnets, south Mt. Northfield.
2122 Iron Pyrites, Saddle Mount, Adams.
2123 Mag. Ox. Iron, Warwick.
2124 do Orange, bowlder.
2125 Micaceous Ox. Iron, Montague.
2126, 2127 Kyanite? (fibrolite,) Palmer.
2128 Zoisite in Quartz, Heath.
2129 do and hornblende, do.
2130 Epidote and Garnet, Warwick.
2131, 2132 do and quartz, do
2133 Garnet and Mag. Ox. Iron, do.
2134 do do bowlder, Orange.
2135 do and Quartz, Warwick.
2136 schorl in quartz, Northfield.
2137 Fibrolite in mica slate, Phillipston.
2138, 2139, Masonite, (Jackson,) Auburn.
2140 do Warwick, R. Island.

## *Talcose Slate.*

638 Talcose slate, Saddle mountain.
639 do Florida.
640 do W. Stockbridge.
641 do Saddle Mountain.
789 Scaly greenish Talc, serpentine locality, Westfield.
790 do near the steatite, Middlefield.
791 Foliated light green do Rowe.
792 do Middlefield.
793 do Windsor.
794 Green steatite or nearly compact talc, Zoar.
795 Steatite with rhomb spar, do
796 do Windsor, N. W. part.
797 do with bitter spar, do N. E. part.
798 do with brown spar, Smithfield, R. I.
799 do Middlefield.
800 do bored for aqueduct pipe, Grafton, Vt.
801 do very fine, Blanford.
802 do Somers, Ct.
803 do Groton.
403 and 1548 do from Gneiss, Worcester.
804 do with asbestus, New Salem.
805 do passing into serpentine, do
806 Between steatite and chlorite from a bowlder, originally from Whitingham, Vt. Conway.
807 Dark green scaly chlorite with feldspar, Cummington.
808 Finer grained, do Goshen.
809 Slaty Chlorite, Smithfield, R. I.
810 do with the steatite, Middlefield.
811 Chlorite Slate, Peru.
812 do with rutile and feldspar, Windsor.
813 Talco-chloritic Slate, Little Compton, R.I.
814 do Smithfield, R. I.
815 do epidotic, Cumberland, R. I.
816 do do and passing into hornblende slate, Smithfield, R. I.
817 Talcose Slate, talc and quartz, Little Compton, R. I.
819, 820 do do Hawley.
821 do greenish, soapstone quarry, Middlefield.
822 do Plainfield.
824 do Florida.
825 do Lenox.
826 Talcose Slate, talc, quartz, and mica, Hawley.
827 do Iron mine, Somerset, Vt.
828 do east side of serpentine, Chester.
829 do Barre.
830, 831 do Rowe.
832 Talc and Limestone, Whitingham, Vt.
833 Talc, quartz, and Carbonate of Iron, Hawley.
834 Quartz with Hydrate of Iron, do
835 Talc, Quartz, and Hornblende, do
836 do Charlemont.
837, 838, 839 do Hawley.
840 Talc, quartz, and Feldspar, Smithfield, R. I.
841 do porphyritic, Hawley.
842 Talcose Slate, with octahedral oxide of Iron, Hawley.
843 do do Blanford.
844 Micaceous Oxide of Iron, Hawley.
845 Mag. Ox. Iron, Native Magnet, Somerset, Vt.
846 do Cumberland R. I.
847 do porphyritic with crystals of feldspar, do
848 Porous quartz with hydrate of Iron, gangue of gold, Somerset, Vt.

849, 850 Poros quartz, in talcose slate, with Hydrate of Iron, for comparison, Virginia.
851 Pyrolusite, Plainfield
852 Maganese Spar, Cummington.
853 White bitter spar, Middlefield, Soapstone Quarry.
854 do with green foliated talc, do
855 Salmon colored do do do
856 Miascite, Zoar.
857 do do
858 Asbestus, do
859 do Pelham.
860 do Blanford.
861 do Shutesbury.
862 Tremolite, probably from Soapstone Quarry, Middlefield.
863 Fibrous Hornblende in Quartz, Plainfield.
864, 865 Fasciculite in talcose slate, do
866 Crystalized Actynolite, in talc, Blandford.
867 do Windsor.
868 do from Soapstone Quarry, Blanford.
869 do radiated, do do
2141, 2142 Steatite, Chester, W. part.
2143 do Rowe
2144 do Petersham, W. part.
2145, 2507 do Andover, E. part.
2146 do bowlder, Warren.
2147 do Cheshire.
2506 do Fitchburg.
2148 Talcose slate with hornblende and iron pyrites, Monson.
2149 do Saddle Mt. N. end, Adams.
2150 do Mt. center of W. Stockbridge
2151 do Top of Tom Ball, Alford.
2152 do Taconic, Alford.
2153 do do do with mag. ox. iron.
2154 do Richmond.
2155 do Saddle Mt. E ridge.
2156 do Hancock.
2157 do do E. part
2158 do Taconic Mt. Boston Corner.
2159 do Kent's quarry, N. Ashford.
2160 do with mag. ox. iron, do
2161 do Bashapish Falls, Mt. Washington.
2162 do Mt. Everett, top, do
2163 do do do
2164 do Taconic, W. of Williamstown.
2165 do do do
2166 do porphyritic, Mt. Everett.
2167 do in the hollow, Mt. Washington.
2168 do Hoosac Mt. W. part Adams.
2169 do Taconic, Williamstown.
2170 Chlorite Slate with pyrites, Hawley.
2171 do W. Stockbridge. W. part
2172 do Hancock
2173 Talcose Slate and Epidote, Hancock.
2174 do and chlorite, bowlder, Medfield.
2175 do with hornblende, Monson.
2176 Chlorite and Quartz, Hancock.
2177 do Taconic, Williamstown
2178 Chlorite Slate, W. Stockbridge.
2179 Mag. ox. iron, Chester, W. part.
2180 Crystalized hornblende? in Talcose Slate, Chester, W. part.

## *Serpentine.*

870 Compact noble Serpentine, polished, Lime Quarry, Newbury.
871 do with massive garnet, polished, do
872 do with green aminanthus, do
873 Common Serpentine, compact, Newbury.
874 do do Chester, West part
875 do do polished, Middlefield.
876 do slaty, Chester, West part.
877 do with grains of chromite of iron. Windsor, N. E. part.
878 do do N. W. part.
879 do in place, Blanford.
880 do a bowlder, do
881 Black compact Serpentine, Newport, R. I.
882 Variegated do do
883 Dark green compact do a bowlder, Leverett.
884 Dark gray compact do Lime Quarry, Chelmsford.
885 Dark green do with veins of amianthus and Deweylite, Russell.
886, 887 Compact do with a talcose glazing Zoar.
888, 889 Serpentine, steatite, and brown spar, do
890 Black do and talc, or talc passing into serpentine, New Salem.
891 do and do polished, Pelham.
892 Dark green do with do do Blanford.
893 Black do with do and actynolite, Westfield.
894 Light green compact do polished Russell.
895 Black compact do with talc, schiller and calcareous spar, polished, Granville.
896, 897, 898 Serpentine and carbonate of lime, (*Ophicalce grenue* Al. Brongn.) polished, Westfield.
899 Serpentine and carbonate of lime, Westfield.
900 Compact Feldspar, Lime Quarry, Newbury.
901 Compact Scapolite? perhaps petalite, Westfield.
902 Mammillary Chalcedony, Blanford.
903 Yellow Jasper, Middlefield.
904 Chalcedony? do
905 Drusy Quartz, do
906 Satin Spar, Lime Quarry, Newbury.
907 Tremolite, do do
908 Mussite, Blanford.
909 Massive Garnet? Westfield.
910 Actynolite, do
911 do resembling asbestus, do
912 Chromite of Iron, massive, Blanford.
913 do in Serpentine, do
2181 Serpentine, Lynnfield.
2182 do polished, do
2183 Carbonate of Magnesia on Serpentine, do
2184 Diallage in Serpentine, Sodom Mt. Southwick.
2185 Serpentine, Cheshire, S. of M. House.
2186 do bowlder, Russell.

2498, Chromite of Iron, Chester, W. part.
2629 Serpentine, Rail Road, Chester.
2630 do dark colored do
2631 do with Schiller Spar, do

## *Hornblende Slate.*

914 Lamellar black Hornblende, hornblende rock, Granville.
915 do Belchertown.
916 do with garnets, Norwich.
917 do Belchertown.
918 Finer do hornblende slate, South Hadley Canal.
919 Fibrous Hornblende, do Enfield.
920 Somewhat granular, do do Middlefield.
921 Fibrous hornblende, Leverett.
922 do do Florida
923 Compact do Lincoln.
924 do do Smithfield, R. I.
925 do do Marlborough
926 Fibrous do hornblende slate, Shelburne.
927 do do Banks of Merrimack R.
928 do do Whately.
929 Hornblende and Feldspar, Sudbury.
930 do do hornblende slate, Bernardston.
931 do do rhomboidal, Whately.
932 do do hornblende slate, Ware.
933 do do compact, Smithfield, R.I.
934 do do not slaty, Gill.
935 Quartz and feldspar, a vein in greenstone, do
936, 937, 938 Hornblende and Feldspar, Whately.
939, 940 Hornblende and Feldspar, coarsely granular, hornblende slate, Ware.
941 do chiefly hornblende, (hornblende slate,) Mouth of Miller's R.
942 do feldspar in distinct layers, Dana.
943 Hornblende, Feldspar, and Mica, Plumbago Mine, Sturbribge.
944 do porphyritic, (smoothed,) Heath.
945 do do (bowlder,) S. Hadley Canal.
946 do do do Amherst.
947 do and compact feldspar, Whately.
948 do and feldspar, the latter compact and with a crystaline form, Easton.
949 do do Canton.
950 do do Plymouth.
951 do do Whately.
952 do and Quartz, with a vein, Becket.
953 do do with a vein of graphic granite, Williamsburg
954 do do Shelburne Falls.
655 do do with a vein of quartz, Warwick.
656 do do hornblende fibrous, Hawley.
957 do do and feldspar, the hornblende fasicular, Conway.
958 Hornblende, Feldspar, and Mica, Amherst.
959 do with augite, Becket.
660 do Stow.
961 Hornblende, feldspar and mica, Dracut.
962, 963 do with granite, Leverett.
964 Hornblende and Epidote, Granville.
964 1-2 do in contact with serpentine, Blanford.
665 do rhomboidal, Whately.
966 Crystalized feldspar in hornblende slate, do
967 Hornblende and Chlorite, do
968 Actynolite Slate—actynolite quartz and feldspar, Shutesbury.
969 do Belchertown.
970 Hornblende Slate, with a layer of epidote Pelham.
971 Crystals of Hornblende in hornblende slate, do
2187 Hornblende, massive, Sturbridge near locality of plumbago.
2188 do do Northfield W. of Ct. river.
2189, 2190, 2191, 2192, 2193 do and feldspar, Tolland.
2194 do massive, bowlder, Dedham.
2195 Hornblende Rock, Methuen W. part.
2196, 2197, do with feldspar, Brimfield.
2198 do porphyritic, Monson.
2199 do Methuen W. part.
2200 Hornblende Slate, Orange, E. part.
2201 do Wendell.
2202 do Mt Grace, Warwick.
2203 do with feldspar, Wilbraham.
2204 do do Granville.
2205 do do Warwick.
2206 do do Granby, S. E. part.
2207 do do Dana.
2208 do do and mica, New Bedford.
2209 do epidotic, Ludlow.
2210 do with feldspar and mica, Palmer.
2211 do do Ludlow.
2212 do do Orange, S. village.
2513 do do South Mt. Northfield.
2214 do do Wendell.
2215 do striped, Boxford.
2216 do epidotic, Holliston.
2217 do chloritic, Northfield, W. of Ct. River.
2218 Hornblende and feldspar, Concord.
2219 Hornblende talc and epidote—passing into sienite, Beverly.
2220 do Rail Road Cut, Natick: smoothed on one side by sliding.
2221 Hornblende with epidote and calc. spar Lynnfield.
2222 do and chlorite, Wrentham, N. part
2223 Aggregate of hornblende, quartz and feldspar, structure mechanical: Chesterfield.
2224 Hornblende Slate, chloritic and with iron pyrites: Orange, E. part.

2225 Zeolite on hornblende, Sodom, Wilbraham. Rail Road Cut.
972 Granitic Gneiss, Pelham.
973 do Templeton.
974 do Brookfield.
975 do New Braintree.
976 do Pelham.
977 do Paxton.
978 do Petersham.
979 do granular, Monson.
980 do Athol.
981 do Princeton.
982 do Blanford.
983 Sienitic Gneiss—Gneiss with Hornblende, Mendon.
984 Granitic Gneiss? texture somewhat mechanical, Bolton.
985 do Worcester.
986 do do
987 do chiefly flesh colored feldspar and quartz, Sudbury.
988 do slightly talcose, N. Brookfield.
989 do somewhat schistose, Rochester.
990 do do Oxford.
991 do Sudbury.
992 do (smoothed,) Billerica.
993 Schistose Gneiss, Dudley.
994 do Purgatory, Sutton.
995 do granular, Wilbraham.
996 do Mouth of Miller's River, Montague.
997 do Buckland.
998 do Shelburne Falls.
999 do Amherst.
1000 do mica predominating, New Bedford.
1001 do passing into mica slate, Worcester.
1002 do do Paxton.
1003 do do Hardwick.
1004 do Pelham
1005 do feldspar in tuberculous masses, Worcester.
1006 Junction of granitic gneiss and mica slate, do
1007 Schistose Gneiss, Westborough.
1008 do passing into mica slate, (bowlder,) Colerain.
1009 do Windsor.
1010 do feldspar gray, Little Compton, R. I.
1011 do Monson.
1012 do chiefly feldspar, Oxford, East part.
1013 do Florida.
1014 Schistose Gneiss, passing into mica slate with pyrope, Western.
1015 do do Shrewsbury.
1016 do western base of Wachusett, Princeton.
1017 do Grafton.
1018 do Charlton.
1019 do somewhat porphyritic, Harvard.
1020 do talcose? Framingham.
1021 do do? Leverett.

1022 Schistose Gneiss with veins of chlorite, Bolton.
1023 Laminar Gneiss. Windsor.
1024 do Webster, west part.
1025 do Amherst.
1026 do Grafton.
1027 See the No. following No. 778.
1028, 1029 Laminar Gneiss, Pelham.
1030 do Norfolk, Con.
1031 do feldspar, hornblende slate interlaminated, Enfield.
1032 do do Warwick.
1033 do Savoy.
1034 do Windsor.
1035 do Dalton.
1036 do Becket.
1037 do with a vein of granite, Pelham.
1038, 1039 do Douglas.
1040 do becoming porphyritic, Ward.
1041 Porphyritic Gneiss, Pelham.
1042 do feldspar, flesh colored, Amherst.
1043 do with epidote, (smoothed,) Pelham.
1044 do coarse, New Braintree.
1045, 1046 do do Ware.
1047 do Methuen.
1048 do scarcely porphyritic, Paxton.
1049 do Montague.
1050 do passing into schistose. Tolland.
1051 Amphibolic Gneiss, containing disseminated Masses of hornblende. Montague.
1052 do Leverett.
1053 do Enfield.
1054 do Pelham.
1055 Epidotic Gneiss. Amherst.
1056 do Pelham.
1057 do Amherst.
1058 do Grafton.
1059 do Amherst.
1062 to 1065 Augitic Gneiss, Lee.
1066, 1067 Anthrophyllitic Gneiss, Enfield.
1068 Arenaceous Gneiss, Southbridge.
1069, 1070 do Smithfield, R. I.
1071 Talcose Gneiss, do
1072 Gneiss with a serpentine granite vein, Enfield.
1073 Plumbago, the common variety, Sturbridge.
1074 do apparently fibrous, do
1075 do partially crystaline, do
1076 Fuller's earth? In the Plumbago mine do
1077 Hydrate of Iron, (bog ore) in do do
1078 do in Gneiss, North Brookfield.
1079 Garnet and Sulphuret of Molybdenum in gneiss do
1080 Native Alum and Sulphate of Iron on gneiss, Leominster.
1081 do do Barre.
1082 Pyrope Garnet in gneiss, New Braintree.

1083 Pyrope with adularia, Brimfield.
1084 do in gneiss passing into mica slate, Norwich, Ct.
1085 Crystalized feldspar in gneiss, Boxborough.
1086 Green Adularia, with mica (polished) Southbridge.
1087, 1088 Adularia, Brimfield.
1089, 1090 Schorl in quartz from gneiss, Pelham.
1091 Crystalized Sphene in augitic gneiss, Lee.
1092 Crystalized augite and scapolite? do
1093, 1094 Sulphuret of Iron, Hubbardston.
1095 Blue quartz and pyrites, do
1096 Magnetic Oxide of Iron in gneiss, Grafton.
1097, 1098, 1099 Crystalized and Drusy Quartz, Pelham.
1100 Radiated Quartz, Pelham.
1101 Amethystine, do do.
1102 Bluish Mammillary Chalcedony in gneiss, Pelham.
1103 Breccia Agate, (polished,) Rochester.
1104 Gray Copper, perhaps from gneiss, Brimfield?
1105 Actynolite in feldspar, Chelmsford.
2226 Gneiss, granitic, Hubbardston.
2227 do do New Bedford, used in architecture.
2228 do do with garnets, Fairhaven.
2229 do do Quarry, Monson.
2230 do do Rail Road, Middlefield.
2231 do do with epidote, Leverett.
2232 do do West Medway.
2233 do do with schorl, Wendell.
2234 do do Tolland.
2235 do Slaty, Middle Granville.
2236 do do contorted, Sandisfield.
2237 do Cheshire, 1 mile south of M. House.
2238 do granitic, red feldspar, Palmer.
2239 do do Brimfield.
2240 do porphyritic do.
2241 do do with garnets, do.
2242 do do Monson.
2243 do do Rutland.
2244 do slaty, Sandisfield.
2245 do Purgatory, Gr. Barrington.
2246 do with hornblende, Beartown Mt.
2247 do do quarry, Palmer.
2248 do granitic, Brimfield.
2249 do slaty, Sherburne.
2250 do next to quartz rock, Washington.
2251 do granitic, Saddle Mt. Northfield.
2252 do slaty with pyrope and crystals of mica, Erving.
2253 do do Sandisfield.
2254 do do with talc? Montague.
2255 do do do North Adams.
2256 do do Clarksburg.
2257 do rhomboidal, quarry, Palmer.
2258 do slaty, rail road, deep cut, summit level, Washington.
2259 do do Fairhaven.
2260 Gneiss augitic, Washington, N. W. part.
2261 do slaty, Blackstone village, Mendon.
2262 do granitic, Dana.
2263 do slaty do.
2264 do do Ashby.
2265 do do Rail Road, Auburn.
2366, 2267, 2268, do do do with layers of mica slate.
2269 do granitic with hornblende slate, Dartmouth.
2270 do and hornblende slate, Dana.
2271, 2272 do slaty, Hadsell's quarry, New Marlborough.
2273 do do Middle Granville.
2274 do do Royalston.
2275 do rhomboidal, Wales.
2276 do slaty, Sturbridge.
2277 do do Shaker Village, Tyringham.
2278 do do with an incrustration of schorl? Athol.
2279 do slaty, Royalston.
2280 do do Rail Road, Natick.
2281 do do do Washington.
2282 do do Sodom, Wilbraham.
2283 do do Beverly.
2284 do granitic, the original of the buhrstone, Washington.
2285 do do with garnets, Southbridge.
2286 do quartzose, Wendell.
2287 do do firestone, do.
2288 do do Bellingham.
2289 do augitic, do
2290 do do Dracut.
2291 do do Rail Road Cut, Natick.
2292 do? epidotic, bowlder, Carver.
2293 do porphyritic do do
2294 do with pyrope and adularia, Morse's Graphite quarry, Stockbridge.
2295 do do Barre.
2296, 2297 do do Brimfield.
2298 do with garnets, Granville.
2299 Foliated Graphite with feldspar, Sturbridge.
2300 Crystalized hornblende and scapolite, Tyringham.
2301 do with sphene, do.
2302 do and quartz, do.
2303 do and feldspar, do.
2304, 2305 Hornblende and feldspar, deep cut on R. Road, summit head, Washington.
2306 Anthophyllite and garnet, Philipston.
2307 do in gneiss, Barre.
2308 Augite and talc, Cheshire.
2309 do and epidote, Athol.
2310 Iolite in gneiss, Brimfield.
2311, 2312 Adularia, Brimfield.
2313 Rutile on gneiss, Barre, W. part.
2314 Epidote & purp. fluor spar on gneiss, Barre.
2315 Schorl in gneiss, Shutesbury.
2316 do and epidote, Enfield.
2317, 2318 Crystalized feldspar in gneiss, three Rivers, Palmer.

2319 Prehnite on gneiss, Three Rivers.
2320 Zeolite? and feldspar on gneiss, do
2321 Red Calcareous Spar on do do
2322 do and feldspar, do
2323 do on tortuous gneiss, do
2324 Allanite in gneiss, South Royalston.
2325 do do Athol.
2326 Crystalized mica and chlorite in gneiss, Mendon, near Blackstone village.
2327 Contorted hornblendic gneiss, Hardwick.
2328, 2329 Mammillary Chalcedony, Tyringham.
2330 Sulphuret of Molybdenum, Pelham.
2331, 2332 Unknown mineral in pebbles, among the gneiss, Athol.
2508 Amethyst in gneiss, Franklin.
2509 Green Hornstone, Pelham, a bowlder from which Shays' men manufactured their flints.
2614 Pyrope, Morse's Graphite Mine, Sturbridge.
2615 do two specimens cut and polished. Same locality.
2616 Plumbago, in gneiss, Washington.
2617 Greenish feldspar with ore of copper? Rail Road, Russell.

UNSTRATIFIED ROCKS.

## *Greenstone.*

1106 Common greenstone, hornblende and feldspar, Sunderland
1107 do do Deerfield.
1108 do do Mt. Holyoke.
1109 do do Turner's Falls.
1110 do do Mt. Tom
1111 do do in gneiss Pelham.
1112 do do epidotic, Chelsea.
1113 do approaching to sienite, Newburyport.
1114 do Lexington.
1115 do do do Holliston.
1116 do do do Concord
1117 See the No. following 1205.
1118 Common Greenstone, epidotic, do Waltham.
1119 do Nahant
1120 vein in clay slate, Charlestown.
1121 Coarse Greenstone passing into sienite, Charlestown.
1122 Greenstone passing into sienite (a bowlder,) West Springfield.
1123 do do Holliston.
1124 do do Dover.
1125 do do Stoughton
1126 do do Easton
1127 do the feldspar in bronze colored folia, West Springfield.
1128 do do Mt. Holyoke.
1129 do the ingredients distinguished with difficulty, Hingham.
1130 do do Newton.
1131 Greenstone passing into sienite, Blue Hills.
1132 do Quincy.
1133 do from a vein in gneiss, Rutland.
1134 do Nahant.
1135 do from a vein in gneiss Northfield.
1136 Columnar Greenstone, 4 sided prism, Mt Holyoke.
1137 do 5 sided prism, do
1138 do 3 sided prism. do
1139 Curved exfoliated mass from a column, do
1140 Compact Greenstone, the ingredients indistinct, Nahant.
1141 do Blue Hills.
1142 do a bowlder, Framingham.
1143 do from a vein in granite, Foxborough.
1144 Chiefly greenish compact feldspar, Salisbury.
1145 do Rowley.
1146, 1147, 1149, 1150 do Dedham.
1148 Indurated Clay, Titan's Pier, S. Hadley.
1151 Common Greenstone with reddish carbonate of lime, Deerfield.
1152 to 1155 Hornblende, Augite? and Feldspar, Nahant.
1156 Porphyritic Greenstone, (smoothed) Cape Ann.
1157 do Easton.
1158 do (smoothed) Salem.
1159 do imbedded crystals of Karinthin (smoothed) Ipswich.
1160 do reddish, Turner's Falls
1161 do base reddish, Deerfield.
1162 Greenstone porphyritic and epidotic, with iron pyrites, Topsfield.
1163 do do base wacke-like, Turner's Falls.
1164 do do do Deerfield.
1165 Slaty Greestone, micaceous, Reading.
1166 Amygdaloidal Greenstone, nodules calcareous, Deerfield.
1167 do nodules siliceous, S. Hadley Canal.
1168 do nodules calcareous, Deerfield.
1169 do do Turner's Falls.
1170 do cavities empty, toadstone, Gill.
1171 do do do Mt. Holyoke.
1172 do nodules siliceous, Titan's Pier.
1173 do nodules foliated chlorite, Turner's Falls.
1174 do nodules earthy chlorite, West Springfield.
1175 do nodules calcareous, Rowley.
1176 Concretions from Greenstone, Deerfield.
1177 do Mount Holyoke.
1178 Trap Tufa, or tufaceous greenstone, South Hadley Canal.
1179 do micaceous, Deerfield.
1180 do Titan's Pier.
1181 do cement calcareous spar, Deerfield.
1182 do Northampton.
1183 do Mount Tom.
1184 do base reddish, Deerfield,

1185 Junction of Amygdaloid and sandstone. Turner's Falls.
1186 Trap Tufa, West Springfield.
1187 Nodules of Prehnite in greenstone, Greenfield.
1188, 1189 Chalcedony in do Deerfield.
1190 do do Greenfield.
1191 Large Agate, of chalcedony carnelian and quartz, Deerfield.
1192, 1193 Amethyst in greenstone, do
1194 Black Augite do do
1195 Prehnite, Augite and Calcareous Spar, do
1196 Pseudomophous Quartz, with prehnite, do
1197 Calcareous Spar, prehnite, &c. do
1198, 1199 Chlorophœite in trap, Turner's Falls.
1200 Lincolnite and chabasie in greenstone, Deerfield.
1201 do do Deerfield.
1202 do and chabasie do do
1203, 1204 do covering the surface, do
1205 Radiated mineral, perhaps Lincolnite, on greenstone, Deerfield.
1117 Crystalized Smoky quartz, from Greenstone, West Springfield.
2333 Greenstone from Gneiss, Monson
2334 do do Montague.
2335 do veins in sienite, Holliston.
2336 do tufaceous do Dedham
2337 do from Gneiss, Hubbardston.
2338 do do Westminster.
2339 do do Belchertown.
2340 Porphyry: Vein No. 2, Fig. 147, in Sienite, Cohassett
2341 Greenstone in sienite, Rail Road Cut, Needham.
2342 do from Gneiss, Philipston.
2343 do chiefly feldspar, do do
2344 do bowlder, Groton.
2345 do with epidote, Beverly.
2346 do chloritic, Rail Road, Natick.
2347 do vein No 3, Fig. 147, Cohassett; containing an unknown bronze colored mineral.
2348 Wacke, from a vein in conglomerate, Roxbury. Mr. Dudley's farm.
2349 Trap compact, same place.
2350 Quartz and wacke, same place.
2351 Greenstone, acted upon at the surface by weather. Pelham.
2352 Greenstone, slaty, from a vein Fitz-William, N. H.
2353 Trap, vesicular, reddish, Sunderland.
2354 do do black, Mt. Toby.
2355 do do cavities cylindrical, do.
2356 do do with Zeolite, Deerfield.
2357 Greenstone porphyritic, green porphyry, Nantasket Beach.
2358 Trap, porphyritic, Beverly shore.
2359 do do Saugus.
2360 do from a dike, Beverly Bridge, Salem.
2361 Greenstone, porphyritic, bowlder, West Bridgewater.
2362 Greenstone porphyritic, Plymouth.
2363 do do bowlder, Pembroke.
2364 do do Manomet Hill, Plymouth.
2365 do do veins in sienite, No. 1, Fig. 147, Cohassett.
2366 do do No. 1, Fig. 147, same place.
2367 Trap, veins in sienite, Holliston.
2368 Radiated mineral in trap, bowlder, Newbury.
2369 Trap, amygdaloidal, Mt. Holyoke.
2370 Quartz in trap, Mt. Holyoke.
2371 Galena and copper pyrites in a vein in chloritic trap, Canton.
2510 A column of greenstone, Mt. Tom.
2590 Vegetable Remains in trap, a bowlder, Amherst, (See Fig. 96.)
2618 Greenstone, Rail Road, W. Springfield, W. part.
2619 do porphyritic, do
2620, 2621 do amygdaloid, do
2622, 2623 Tufa, do
2624, 2625 Prehnite, on greenstone, do
2626 to 2628 Crystalized Calc. spar on do same place.

## *Porphyry.*

1206 and 1207 Compact Feldspar, Newbury.
1208 do with talc? Newbury.
1209 do with dendritic impressions, Medford.
1210 do with quartz, Natick.
1211 do somewhat foliated, a vein in sienite, Whately.
1212 do somewhat brecciated, Dorchester.
1213 do do Blue Hills.
1214 do a vein in black serpentine, Newbury.
1215 do Nahant.
1216 do slightly porphyritic, Hingham.
1217 do Lynn.
1218 do somewhat foliated. Natick.
1219 do lime quarry, Stoneham.
1220 do variegated, Medford.
1221 do passing into siliceous slate, Malden.
1222 do do with a minute quantity of gold? Blue Hills.
1223 do red, passing into porphyry, do
1224 do do Hingham.
1225 do do Milton.
1226 do do Rowley.
1227 do do Ipswich.
1228 do do metamorphic, Kent's Island, Newbury.
1229 and 1230 do variegated somewhat foliated, Dedham.
1231 Porphyry approaching Sienite (polished) Malden.
1232 do with traces of a slaty structure, Nantasket Beach.
1233 do base purple, (polished) bowlder, Orleans.
1234 do base black, (do) Nantasket Beach.

1235 Porphyry near to amygdaloid, Westboro'.
1236 Between greenstone and porphyry, Ipswich.
1237 do porphyry and compact feldspar, Milton.
1238 Porphyry Blue Hills.
1239 Porphyry dark gray, (polished) Blue Hills.
1240 do do (do) North of Boston.
1241 do containing quartz nodules (polished), Milton.
1242 do light gray, do do
1243 do reddish, Nantasket Beach.
1244 do? perhaps Varioloid Wacke, Newton.
1245 do containing quartz and feldspar crystals, Milton.
1246 do red and green, (smoothed) Malden.
1247 do red with quartz and feldspar crystals, a bowlder, Newport, R. I.
1248 do red, Malden.
1249 do do Lynn.
1250 do red base, Nantasket Beach.
1251 do do (polished) Blue Hills.
1252 do base red (do) North of Boston.
1253 do do (do) Nantasket Beach.
1254 do greenish do Malden.
1255 do lively green, (do) Milton.
1256 do Needham.
1257 do passing into sienite, Malden.
1258 do reddish brown, crystals of feldspar and quartz, polished, B. Hills.
1259 do green, passing into sienite, (smoothed) Malden.
1260 do base dark green, crystals feldspar and quartz (do) Blue Hills.
1261 do variegated, feldspar and quartz crystals (do) do
1262 do base reddish, imbedded crystals chiefly quartz (do) Quincy.
1263 do do do (do) Milton.
1264 Brecciated Porphyry, reddish, (polished) Halfway Rock, Atlan. Ocean.
1265 do (smoothed) Lynn.
1266 do passing into graywacke, (smoothed) Malden.
1267 do (polished) do
1268 do do Nantasket Beach.
1269 do greenish, Malden.
1270 do betraying a former slaty structure, Nantasket Beach.
2372 Dendritic Impressions on porphyry, Lynn, rail road.
2373 do on Jasper, Saugus.
2374 do on hornstone or compact feldspar, Holliston.
2375 Vein of Compact Feldspar in serpentine, Devil's Den, Newbury.
2376 Compact Feldspar, red, Newbury.
2377 do? gray, Dedham.
2378 do greenish gray, Newbury.
2379 do with greenstone, Natick.
2380 Porphyry, West Newbury.
2381 do brecciated, Lynn.
2382 do red with a vein of greenish feldspar, Saugus.
2383 do Manomet Hill, Plymouth.
2384 do brecciated, Dedham, W. part.
2385 do with epidote do do
2386 do with veins of compact feldspar, bowlder, Natick.
2387 do Dedham, W. part.
2388 do Sherburne, E. part.
2389, 2390 do Lynn,
2391, 2392 do Manomet Hill, Plymouth.
2393 do bowlder, Medfield.
2394 do brown, Marblehead Neck.

## *Sienite.*

1271 Feldspar and Hornblende, (smoothed) Newbury.
1272 do passing into porphyry do Nahant.
1273 do do Stoneham.
1274 do brecciated, do Foxborough.
1275 do Concord.
1276 do (smoothed) Dover.
1277 do do Reading.
1278 do do Nahant.
1279 do Norfolk County.
1280 do Rowley.
1281 do Hangman's Island, Boston Harbor.
1282 do hornblende in distinct crystals, (smoothed) Dedham.
1283 do do Randolph.
1284 do Reading.
1285 do Cumberland, R. I.
1286 do epidote, Dedham.
1287 Feldspar, Quartz and Hornblende, Salisbury.
1288 do Manchester.
1289 do Quincy Granite, Quincy.
1290 do do (smoothed) Quincy.
1291 do (bowlder) Mansfield.
1292 do Franklin.
1293 do (smoothed) Danvers.
1294, 1295 do do Squam, Gloucester.
1296, 1297 do do Sandy Bay, do
1298 do do Squam, do
1299 do do North Bridgewater.
1300 Quartz and Feldspar, do Manchester.
1301 do do Foxborough.
1302 do do Easton.
1303 do feldspar mostly compact, (smoothed) West Cambridge.
1304 do do Hingham.
1305 do do Sherburne.
1306 do feldspar blood red, (smoothed) a bowlder, Marshfield.
1307 do and perhaps hornblende do Scituate.
1308 do do Weston.
1309 do Middleborough.
1310 do Weston.

1311 Quartz and Feldspar, Foxborough.
1312 do Danvers.
1313 Feldspar and quartz, the former compact, Newbury.
1314 do chloritic, the feldspar red and greenish, Saugus.
1315 do do the feldspar compact, close to the jasper, Saugus.
1316 Passing into porphyry, Newbury.
1317 do Manchester.
1318 do Malden.
1319 Feldspar, Hornblende, Quartz and mica, Belchertown.
1320 do (smoothed) do
1321 do do Northampton.
1322 Feldspar, Hornblende, Quartz and Mica, Williamsburgh.
1323 do Whately.
1324 do the hornblende predominating, Northampton.
1325 do with veins of epidote, Whately.
1326 do do
1327 do chiefly feldspar, do
1328 do Gloucester.
1329 Chiefly feldspar and talc or chlorite with veins of epidote, Salisbury.
1330 Feldspar, hornblende ? and mica, (smoothed) Medford.
1331 do coarse a bowlder, Charlestown.
1332 Feldspar, quartz, mica, and perhaps hornblende, Fall River, Troy.
1333 Chiefly feldspar and mica, Bradford.
1334 do with a little quartz and hornblende, Lincoln.
1335 Feldspar, hornblende, and mica, Salem.
1336 Feldspar hornblende and talc, Newbury.
1337 Feldspar quartz and mica, or talc, Franklin.
1338, 1339, 1340 Granite, sienite and greenstone from the same ledge, Stoughton.
1341 Porphyritic sienite, (smoothed) Lexington.
1342 do feldspar and quartz with epidote, (smoothed) Marblehead.
1343 do feldspar bronze colored, Gloucester.
1344 do base green, compact feldspar, crystals flesh red foliated; also quartz and hornblende, West Bridgwater.
1345, 1346 do like the last Abington.
1347 do Plymouth County,
1348 do feldspar, quartz, mica and hornblende, Essex.
1349 Porphyritic Sienite passing to porphyritic greenstone, the crystals nearly compact, Waltham.
1350 Conglomerated Sienite, Whately.
1351 do do
1352 do do
1353 do do
1354 Junction of two varieties of sienite, West Bridgewater.
1355 Vein of graphic granite in sienite, Belchertown.
1356 Vein of nearly compact feldspar in sienite, Southborough.
1357 Irregular vein of granite in sienite, Northampton ?
1358 Vein of compact greenstone in sienite, Nahant.
1359 Veins of feldspar in sienite, Marblehead.
1360 Vein of compact epidote in sienite, Abington.
1361 Vein of red feldspar in sienite, Whately.
1362 Augite, hornblende and feldspar, Belchertown.
1363 Augite and feldspar, the latter almost compact, Amherst.
1364 Sulphate of baryta, Hatfield.
1365 Purple fluate of Lime in sienite, Cumberland, R. I.
1366, 1367, 1368 Drusy crystalized Quartz, Whately.
1369 do with singular cavities, do
1370 Arsenical Iron in quartz from sienite, Newbury.
1371 Galena and Blende in sulphate of baryta, Hatfield.
2395 Coarse Sienite, Andover.
2396 do Beverly.
2397 do bowlder, Newton.
2398 Hornblende, foliated, Beverly.
2399 Sienite, Bradford, E. part.
2400 do Medford.
2401 do foliated greenish, Dedham.
2402 do Cape Ann.
2403 do Manomet Hill, Plymouth.
2404 do with a metallic substance, Sharon.
2405 do feldspar compact, greenish, Foxboro'.
2406 do Hingham.
2407 do bowlder, Waltham.
2408 do Scituate.
2409, 2410 do hornblende in crystals, Medfield, N. E. part.
2411, 2412, 2413 do Kingston.
2414 do Wrentham S part.
2415 do Cohasset.
2416 do Manomet Hill, Plymouth.
2417 do bowlder, Middleborough, E. part.
2418 do Rail Road Cut, Natick.
2419 do Manomet Hill, Plymouth.
2420 do bowlder. Rochester.
2421 do in the village, Hingham.
2422 do Medfield.
2423 do Rail Road Cut, Needham.
2424 do do Natick.
2425, 2426 do Medfield, N E. part.
2427 do Manomet Hill, Plymouth.
2428 do bowlder, Hanover Four Corners
2429 do Scituate.
2430 do bowlder, Pembroke.
2431, 2432 do bowlder, do
2433 do Kent's Island, Newbury.

2434 Sienite, epidotic, Rail Road Cut, Natick.
2435 do Dedham.
2436 do Sharon.
2437 do feldspar red, Dedham.
2438 do feldspar brown, Newbury.
2439 do feldspar red, Manomet Hill, Plymouth.
2440 Sienite, Sharon
2441 do bowlder, Middleborough.
2442 do porphyritic, Beverly.
2443 do Manomet Hill, Plymouth.
2444 do Rail Road Cut, Natick.
2445 do do Needham.
2446, 2447 do do Natick.
2448 do with mica, Belchertown.
2449 to 2453 do do with veins of granite, bowlders, Palmer, W. part.
2454 do Ludlow.
2455 Feldspar, Charlestown.
2456 Specular Oxide of Iron, Dedham.
2457 Crystallized quartz in sienite, Granby, E. part.
2458, 2459 Prehnite in Sienite, Charlestown.
2460 do with calcareous spar, do
2632 Dendrites on Sienite, Dedham, from Dr. Lyman B. Larkin.

## *Granite.*

1372 Feldspar, quartz and mica, common granite, coarse, Russell.
1373 do do Westhampton.
1374 do do S. Hampton, adit.
1375 do do Leverett
1376, 1377 do do Amherst.
1378 do do Granville.
1379 do quartz blue, do Amherst.
1380 do chiefly quartz and mica, do Westford.
1381 Feldspar, Quartz and Mica, chiefly quartz and mica, Amherst.
1382 do do Mouth of Miller's river.
1383 do do Framingham.
1384 do feldspar flesh colored, Blanford.
1385 Feldspar Quartz and mica, common granite, coarse feldspar red, Granville.
1386 do do do Amherst.
1387 do do do New Salem.
1388 do do do Concord.
1389 do quartz yellow do Williamsburgh.
1390 do mica yellow do Chesterfield.
1391 do do do Norwich.
1392 do in bowlders—do easily decomposing, Florida.
1393 do quartz dark gray inclining to purple, Adams.
1394 do feldspar greenish and quartz purplish, Florida.
1395 do mica green, coarse, Cummington.
1396 do quartz smoky gray, do Leverett.
1397 do feldspar bluish, do do
1398 do feldspar blue, do do
1399 do feldspar nearly compact, do Heath.
1400 do do do Amherst.
1401 Granite, (gneiss ?) Ashburnham.
1402 do of a mechanical aspect, Granville.
1403 do ingredients dark gray, Fall River.
1404 do (gneiss ?) Leominster.
1405 do Smithfield, R. I.
1406 do passing into sienite, rather fine, Bristol, R. I.
1407 do junction of coarse and fine grained, Williamsburgh.
1408 do (gneiss ?) Top of Wachusett, Mt.
1409 Quartz and mica, coarse, Westfield.
1410, 1411, 1412 Quartz, mica and feldspar, fine grained, bowlder, S. Hadley.
1413 do feldspar red, (smoothed) Falmouth.
1414 do do do Rochester.
1415 do do do Wareham.
1416 do reddish gray do Framingham.
1417, 1418 do mica black, fine grained, Cumberland, R. I.
1419 do perhaps sienite, do (smoothed) Medfield.
1420 do rather fine grained, Carver.
1421 Feldspar, quartz and mica, or Talc, Weston.
1422 do do eastern part of the State.
1423 Feldspar, Quartz, and Mica, bowlder, fine grained, Adams.
1424 do feldspar purplish, Belchertown.
1425 do evidently recomposed, from a vein, Westfield.
1426 Feldspar, Quartz and Mica, fine grained, quarried, Ashburnham.
1427 do with small garnets, Acton.
1428 do fine grained, Whately.
1429 do do Conway.
1430 do do Holliston.
1431 do chiefly quartz and feldspar, Dedham.
1432 do do Chester.
1433 do feldspar mostly foliated, gray, but some of it compact and greenish, quartz gray, approaching to granular, mica black (smoothed) Pilgrim Rock, Plymouth.
1434 do similar to the last, do
1435 Feldspar Quartz and Mica, fine grained, Acton.
1436 do chiefly quartz, Sudbury.
1437 do passing into porphyry, Halifax.
1438 Feldspar, Quartz, and Talc? Duxbury.
1439 Feldspar and quartz, perhaps sienite, Newbury.
1440 Feldspar, Quartz, and Mica, apparently stratified, Worcester.
1441 do passing into mica slate, Norwich.
1442 do do Colerain.
1443 do mica black, resembling sienite, smoothed, Dover.
1444 do fine grained, S. Hampton Adit.
1445 do quarried, do Tyngsborough.
1446 do do Norwich.
1447 do wrought, do Dover.
1448 do mica nearly wanting, (smoothed) Dover.
1449 do fine grained bowlder, Amherst.

1450 Granite quarried, (smoothed) Concord.
1451 do feldspar reddish, mica scarcely present, (smoothed) Waltham
1452 do very fine grained, decomposing at the surface, (smoothed) Sharon.
1453 do quarried, (smoothed) (Chelmsford granite,) Westford.
1454 do do (do) Fitzwilliam, N. H.
1455 do do (do) porphyritic, Pelham. N. H.
1456 do do (do) Fitchburg.
1457 do do (do) Ashby.
1458 do do (do) Williamsburgh.
1459 Feldspar, Quartz, and talc, Dedham
1460 Feldspar, Quartz, and mica, resembling sienite, Cumberland, R. I.
1461 Feldspar, Quartz, and Mica and Talc, coarse, bowlder, Amherst.
1462 Pseudomorphous granite, Williamsburgh.
1463 Porphyritic Granite, Chester.
1464 do bowlder, Shutesbury.
1465 do very coarse, Harvard.
1466 do fine grained feldspar, nearly compact, bowlder, (smoothed) Turner's Falls.
1467, 1468 do feldspar chiefly compact, in clay slate, Guilford, Vt.
1469, 1470 Chiefly compact feldspar and quartz, do Guilford, Vt.
1471, 1472 Graphic Granite, Willimsburgh.
1473 do Leominster.
1474 do from a vein in quartz rock, Washington.
1475 do Goshen.
1476 do reddish, bowlder, Amherst.
1477, 1478 do flesh red, from red sandstone, Deerfield.
1479 do Warwick.
1480 do with garnets, Goshen.
1481 Junction of Granite and Mica slate, Conway.
1482 Vein of Granite in Mica Slate, do
1483 do do Williamsburgh.
1484 do in the Worcester County Mica slate, Leominster.
1485 Granite at its junction with micaceous limestone, Conway.
1486 Granite with a nodule of mica slate, bowlder, Deerfield.
1487, 1488 Laminated and Tabular Sulphate of baryta, Leverett.
1489 Crystalized calcareous spar, Lead Mine, Southampton.
1490 Argentine, Westhampton.
1491 do showing its junction with granite, do
1492 do Lead Mine, Southampton.
1493, 1494, 1495, 1496 Crystalized Quartz of various colors, Lead Mine, do
1497 Radiated crystalized quartz, Southampton.
1498 Purple Quartz in granite, Florida.
1499 Crystalized smoky Quartz, Goshen.
1500 Massive do Williamsburgh.
1501 Pseudomorphus Quartz, form of calcareous spar, Westhampton.
Pseudomorphous Quartz, form of fluate of lime, Westhampton.
1503 Hornstone, Lead Mine, Southampton.
1504, 1505 Gray and greenish Spodumene, Goshen.
1506 do light rose color, Goshen.
1507 do green and translucent, do
1508 do white and pearly, Sterling.
1509 Straw colored Mica, Tourmaline locality. Chesterfield.
1510 do in distinct crystals, Goshen.
1511 Rose colored Mica, do do
1512 Prismatic Mica, Russell.
1513 Variegated prismatic mica, do
1514 Black mica, do
1515 Plumose Mica, Williamsburgh.
1547 Schorl with terminations, in granite, Chelmsford.
1516, 1517 Indicolite, Goshen.
1528 do light blue, do
1529 do or green tourmaline, do
1520 Yellowish Green tourmaline, do
1521 Indicolite embraced in green tourmaline, Chesterfield.
1522 Green red and blue tourmalines, do
1523 Green tourmaline in quartz, do
1524 do enclosing rubellite, do
1525 Phenacite ? in granite, Goshen.
1526 do rose red, do
1527 do with spodumene, do
1528 do do
1529 Radiated mineral, probably stilbite, do
1530 Fibrous Talc ? Norwich.
1531 do Blanford.
1532 Common Feldspar, Williamsburgh.
1533 Blue do Leverett.
1534 Greenish do Goshen.
1535 Albite (Cleavlandite,) foliated, Chesterfield.
1536 do do New Salem.
1537 do do Goshen.
1538 do coarsely granular, Chesterfield.
1539 do finely granular, Goshen.
1540 Galena in Quartz, Southampton.
1541 do with Blende, Whately.
1542 do with Carbonate of Lead, Southampton.
1543 Blende in Quartz, Northampton.
1544 Pyritous Copper in Quartz, Southampton.
1545 Blende, Galena, and Pyritous Copper, do
1546 Blende decomposing in quartz, Williamsburgh.
1547 See the No. following No. 1515.
1548 See the No. following No 803.
1549 See the No. following No. 774.
1550 See the No. preceding No. 775.
2461 Granite with long prisms of Mica, Russell
2462 do coarse, Northfield.
2463 do South Mt. do
2464 do coarse, Irving.
2465 do do S. Orange.
2466 do feldspar, blue, Clappville, Leicester.
2467 do graphic, Granby, S. E. part.
2468 do feldspar, yellowish, Brimfield.

2469 Granite Feldspar, blue, Hoosac Mt.
2470 do (gneiss?) Clarksburgh, N. W part.
2471 do fine grained, lilac, Three Rivers, Palmer.
2472 do graphic, Sodom Mt. Southwick.
2473 do with red stripes, bowlder, Watertown.
2474 do at the Furnace, Kingston.
2475 do Duxbury.
2476 do Groton, S. E. part.
2477 do red, Topsfield.
2478 do vein in M. Slate Athol.
2479 do coarse vein, Norwich.
2480, 2481, 2482 Mica crystalized, beryl locality S. Royalston.
2483 do foliated, Rail Road, Warren.
2484 Ore of Titanium, Norwich.
2485 Blende in quartz, Norwich 2. Angell's Mine.
2486 Drusy Quartz, do do
2487, 2488 Drusy Quartz in Galena vein, Russell, N. W. part.
2489 to 2496 Crystalized Quartz, Q. Angell's Mine, Norwich.
2497 See No. following No. 1900.
2498 do do 2180.
2499 do do 1844.
2500 do do 1768.
2501 do do 1705.
2502 do do 1584.
2503 do do 1921.
2504, 2505 do do 1559.
2506 See the No. following No. 2147.
2507 do do 2145.
2508 do do 2332.
2509 do do 2332.
2510 Garnet in feldspar, beryl locality, Barre.
2511 Large crystal of feldspar, Beryl locality, South Royalston.
2512 to 2527 See Nos. following 2705.
2528 to 2589 See Nos. following 1800
2590 See Second No. following No. 2371.
2591 to 2613, See No. following 1911.
2614, 2617, See third No. following 2332.
2618 to 2628. See third No. following 2371.
2629 to 2631 See second No. following 2186.
2632 See No. following No. 2460.
2633 Beryls in quartz, South Royalston.
2634 do deep green in do do
2635, 2636 do single large crystals, do
2637, 2638 do in the rock, do
2639 do two specimens cut and polished do
2640 do a single specimen color of the chrysolite, cut and polished, do
2641 Crichtonite, beryl, and crystalized mica in granite, South Royalston.
2642 Beryl in feldspar, Barre, W. part.
2643 do yellowish, do
2644, 2645, Large Crystals of Rutile in granite, Barre, W. part.
2646 See No. following 1988.

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PL. 1.

Thayer's Lith. Boston.

PULPIT ROCK ON MONUMENT M^T

Pl. 2.

Thayer's Lith. Boston.

VIEW FROM MOUNT HOLYOKE.

Pl. 3

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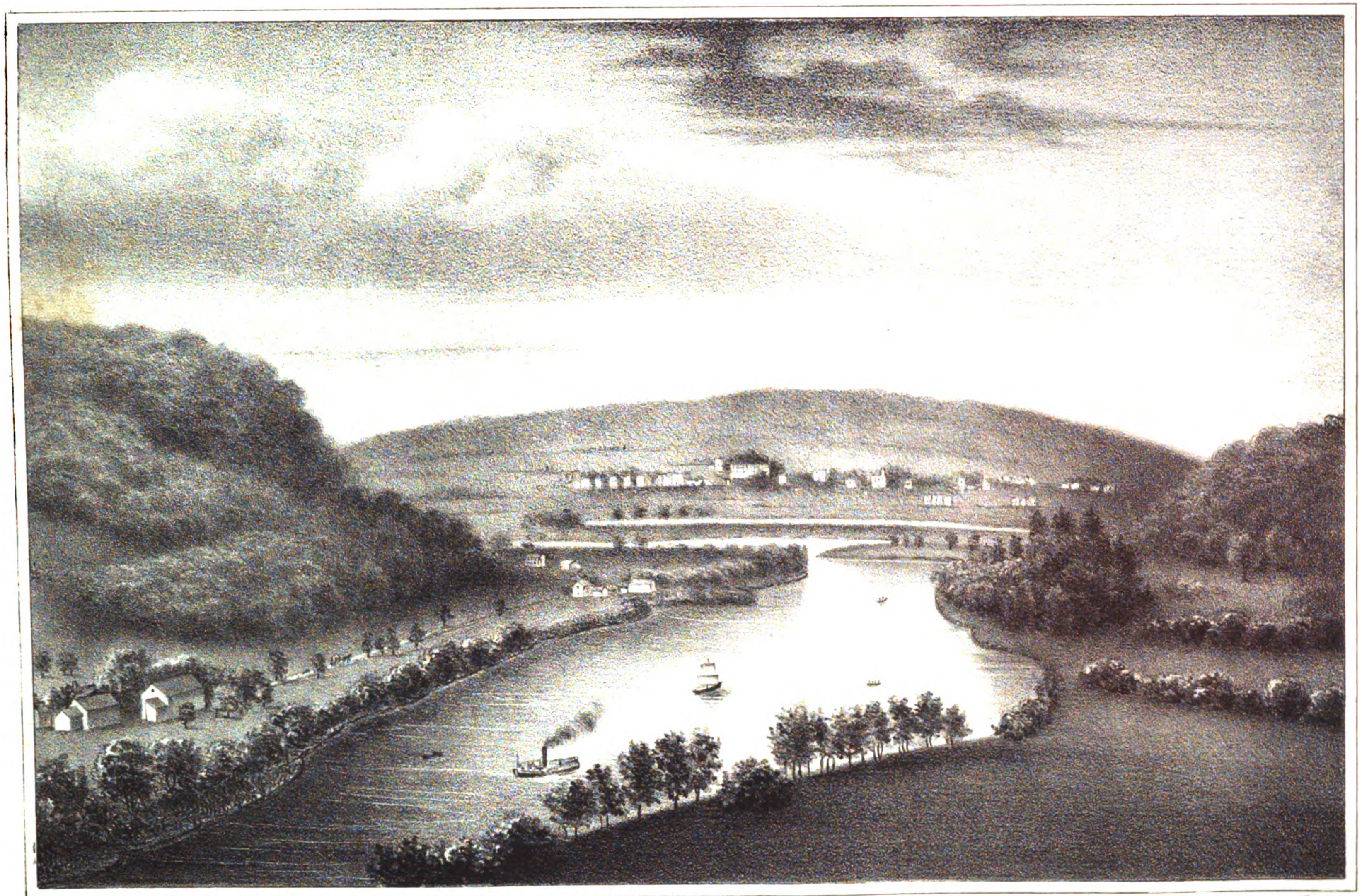
Thayer's Lith Boston.

VIEW IN NORTH ADAMS.

PL. 4



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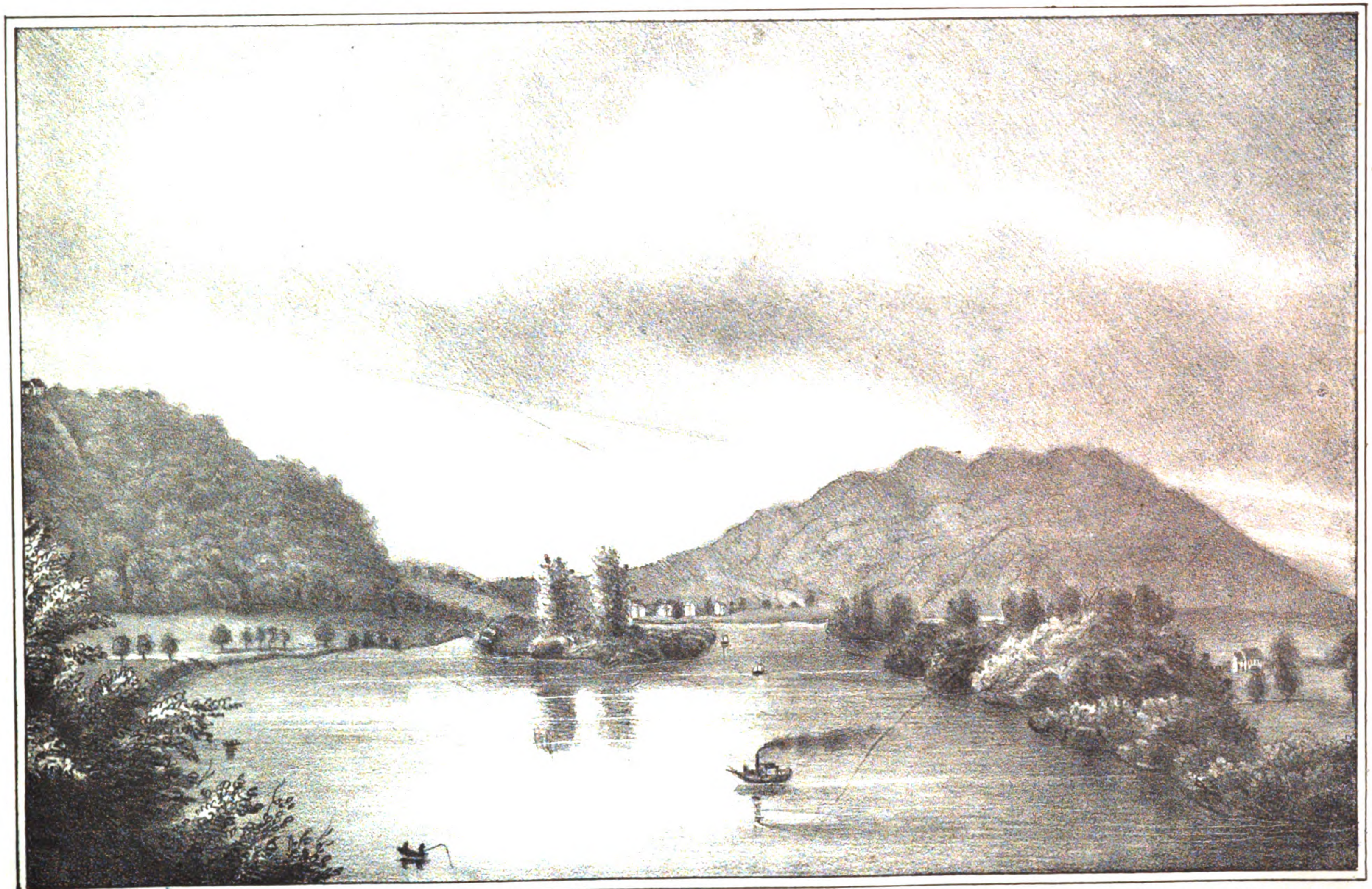
GORGE BETWEEN HOLYOKE AND TOM.

Pl. 5.



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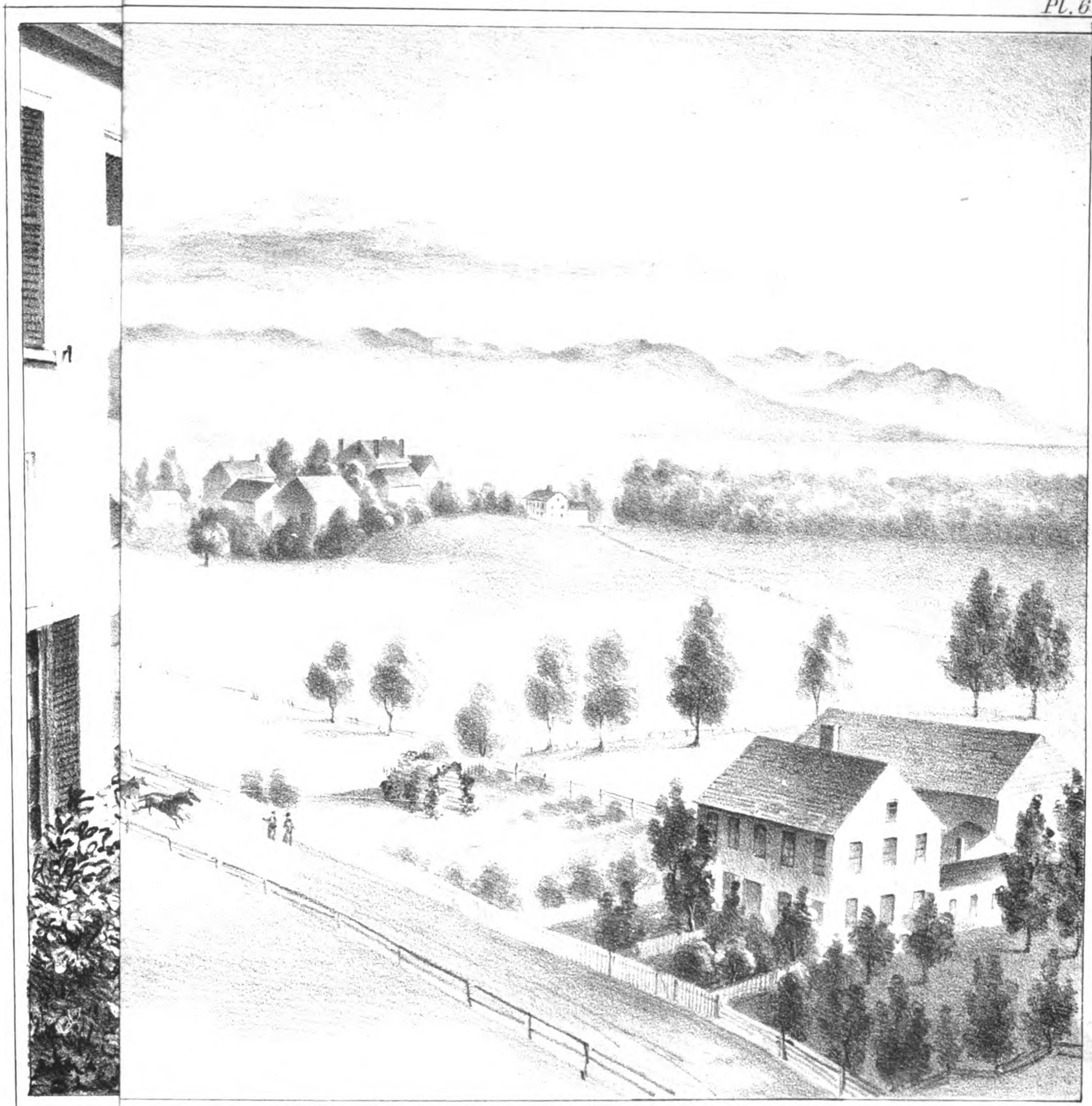
A VIEW IN HADLEY.

Pl. 6.



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Pl. 7.

Miss M. del

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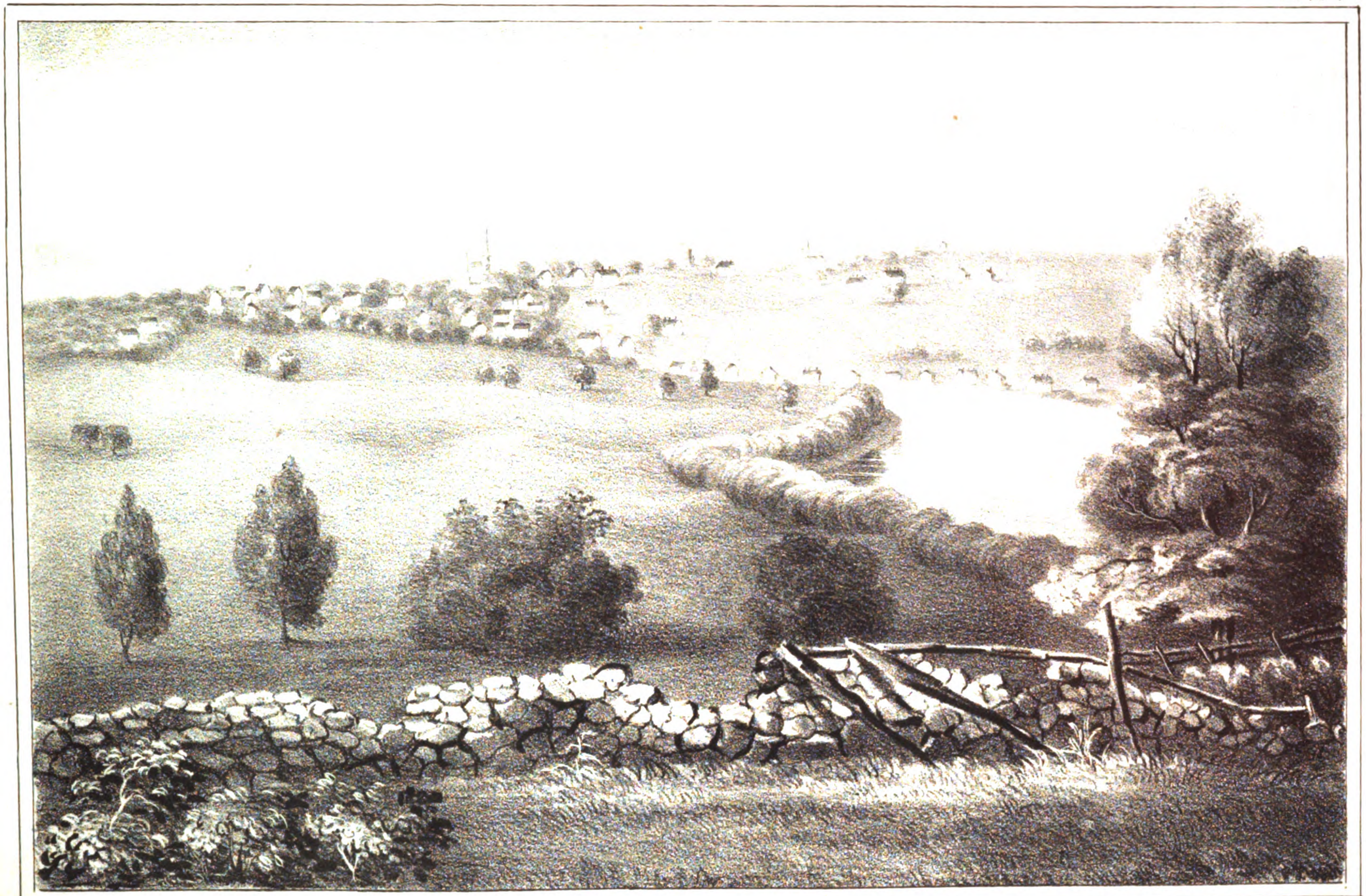
STOCKBRIDGE POND.

Pl. 8.



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VIEW TOWARDS HAVERHILL.

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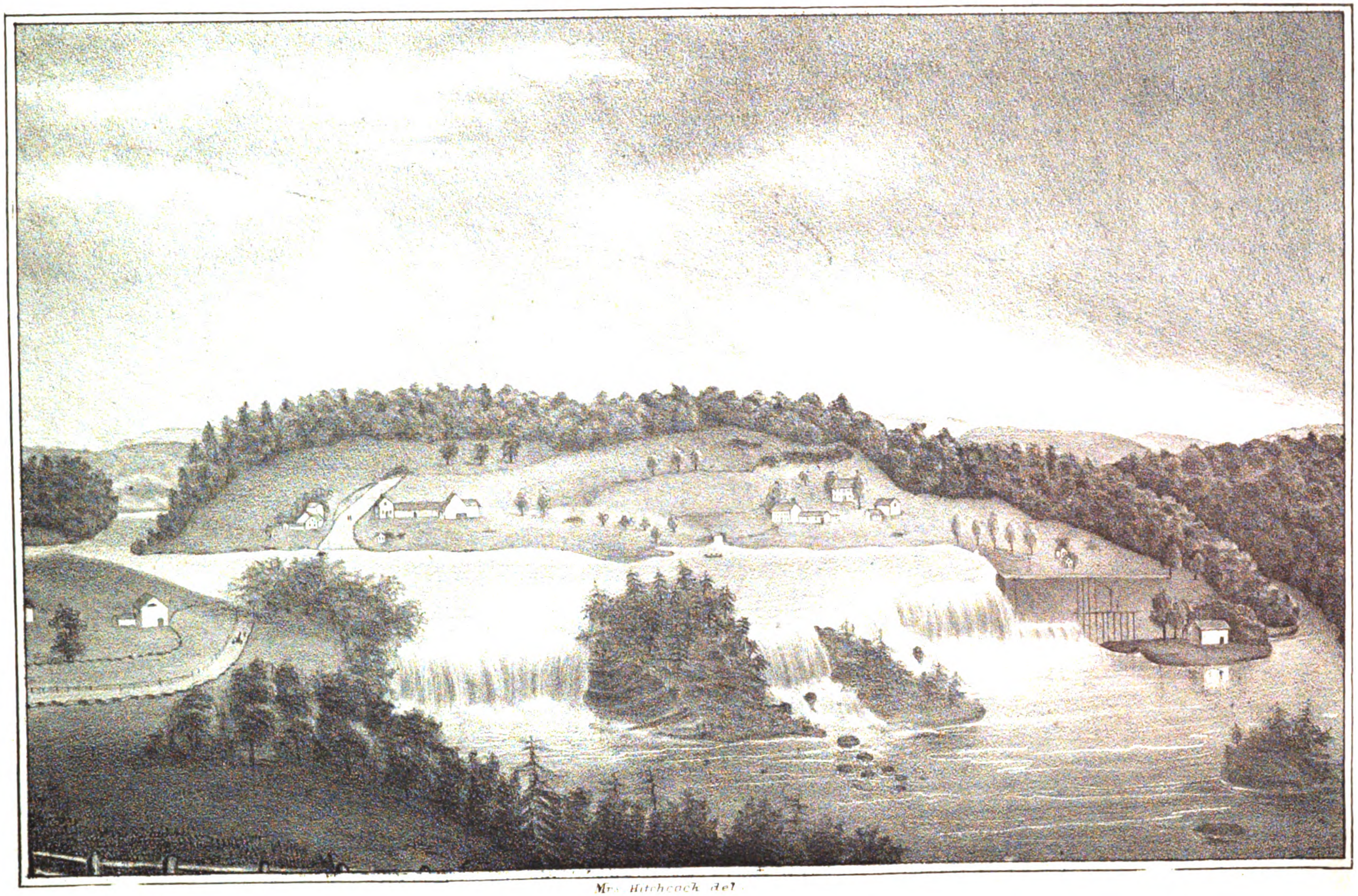
VIEW FROM SAUGUS, TOWARDS LYNN.



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TURNERS FALLS.

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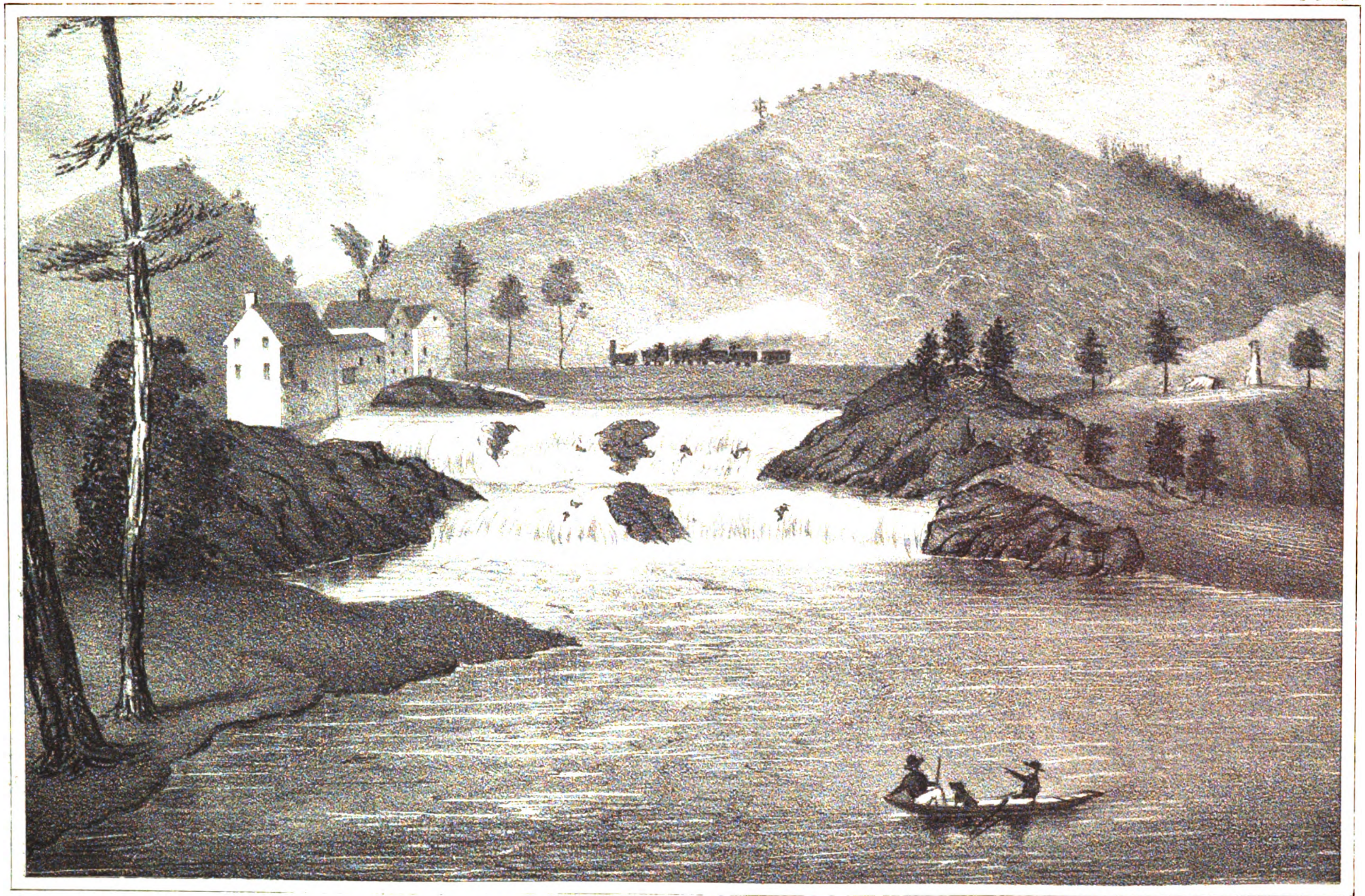
HOLYOKE'S FALLS IN MONTAGUE.

Pl. 12



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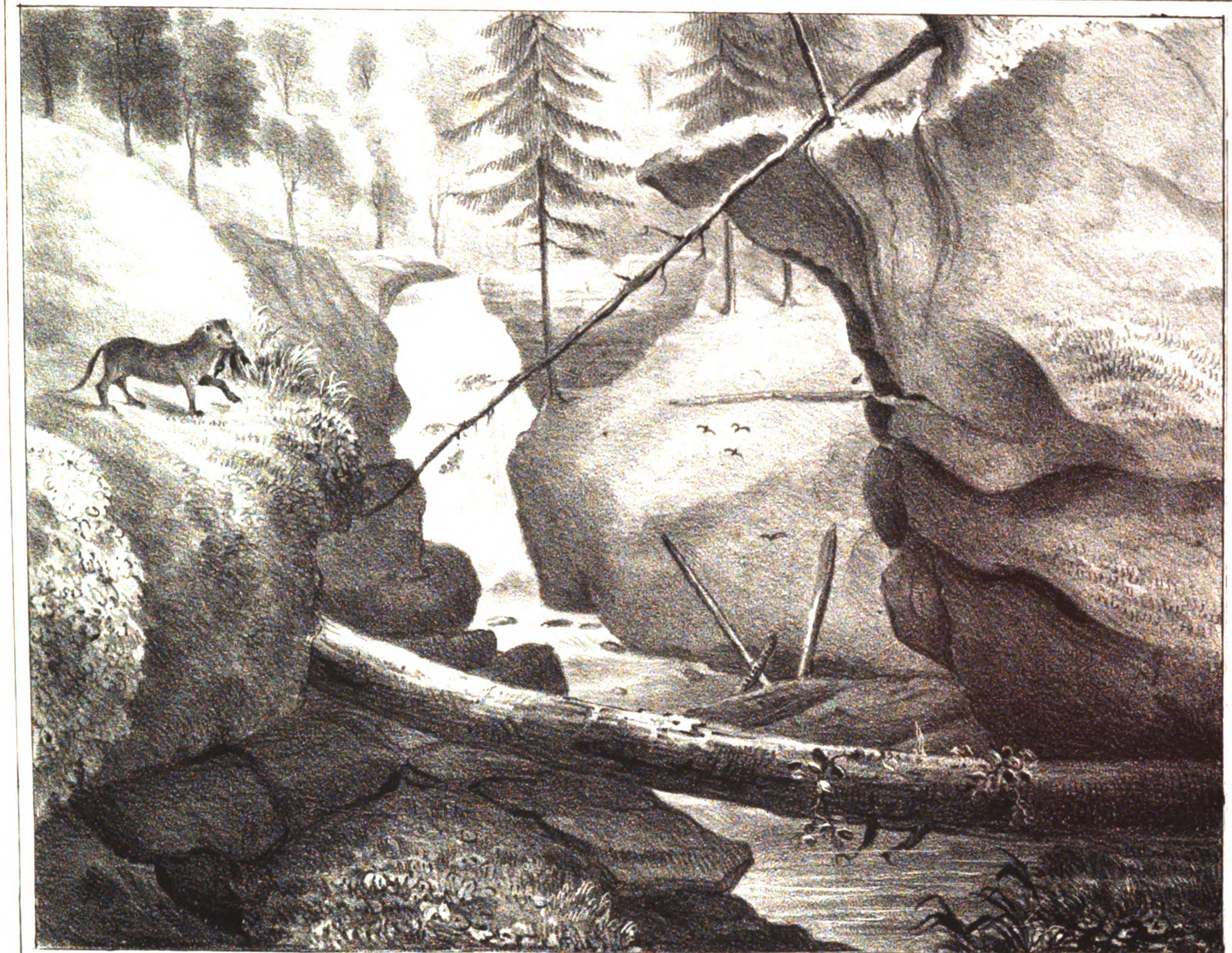
GREAT FALLS; WESTFIELD RIVER, RUSSELL.

Pl. 13.



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GORGE AND FALLS IN ROYALSTON. N.W. PART.

Pl. 14.

H. J Van Lennep del.

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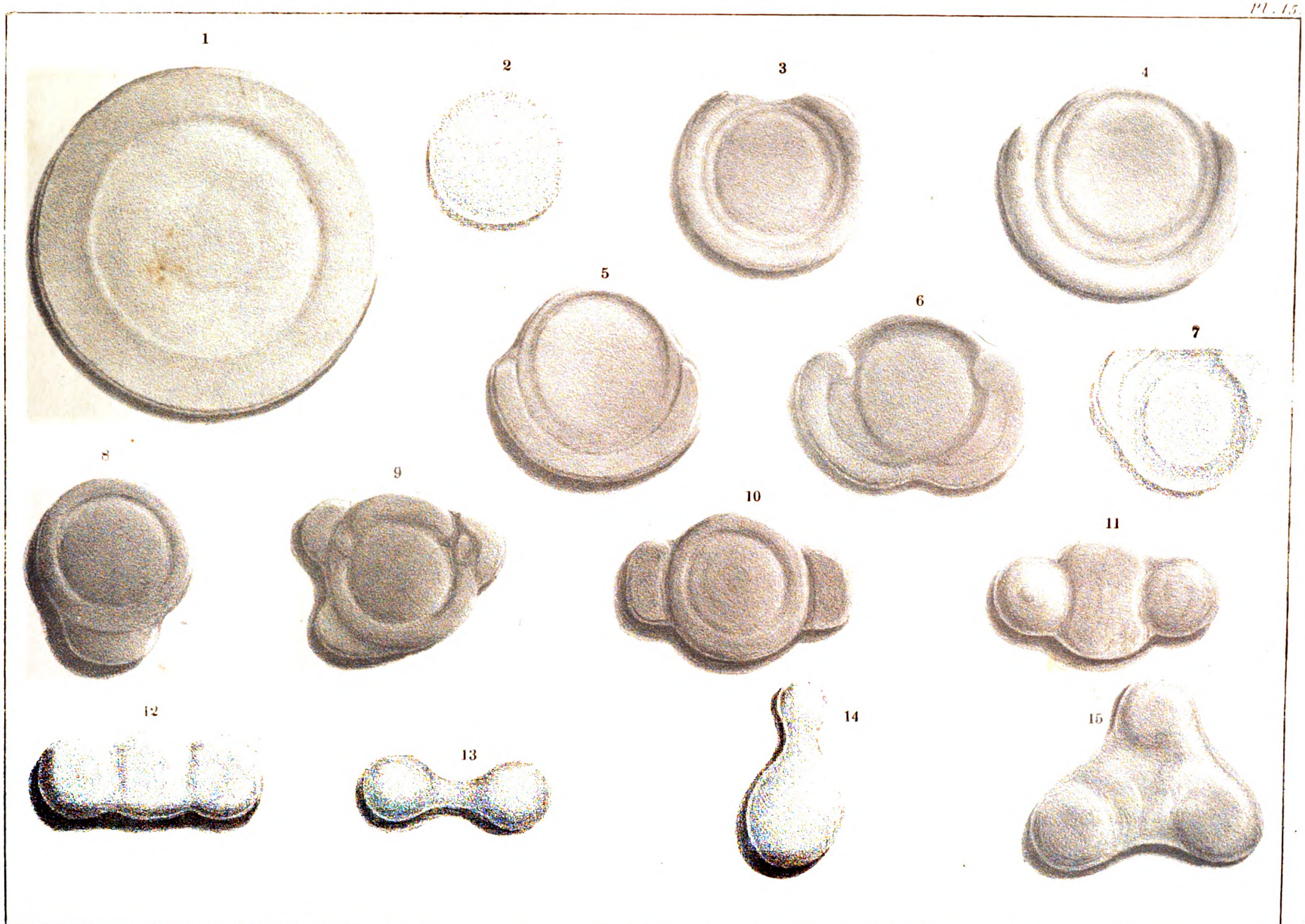
BASHAPISH LOWER FALLS Mt WASHINGTON.

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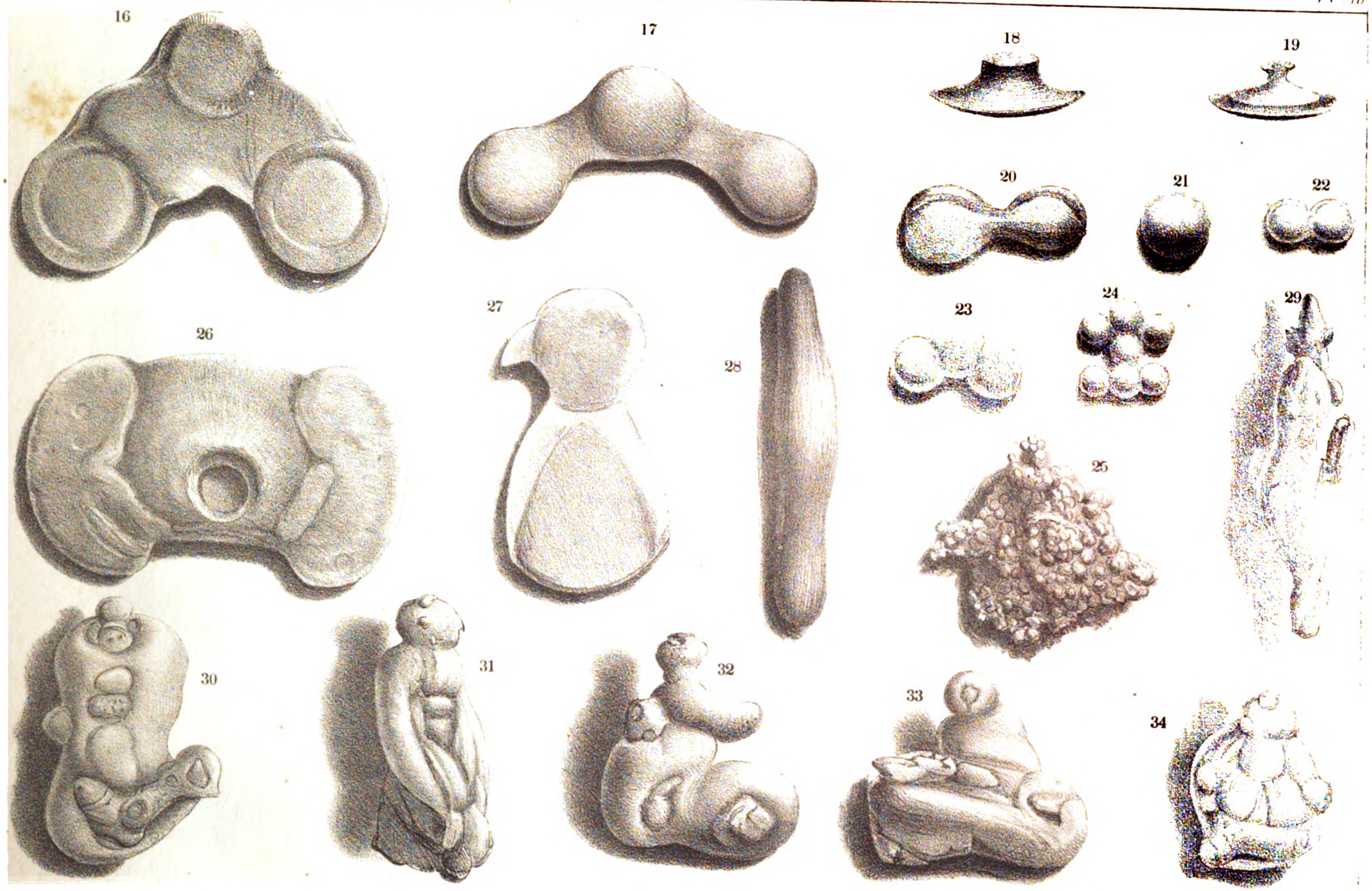
CLAY STONES.

Pl. 16

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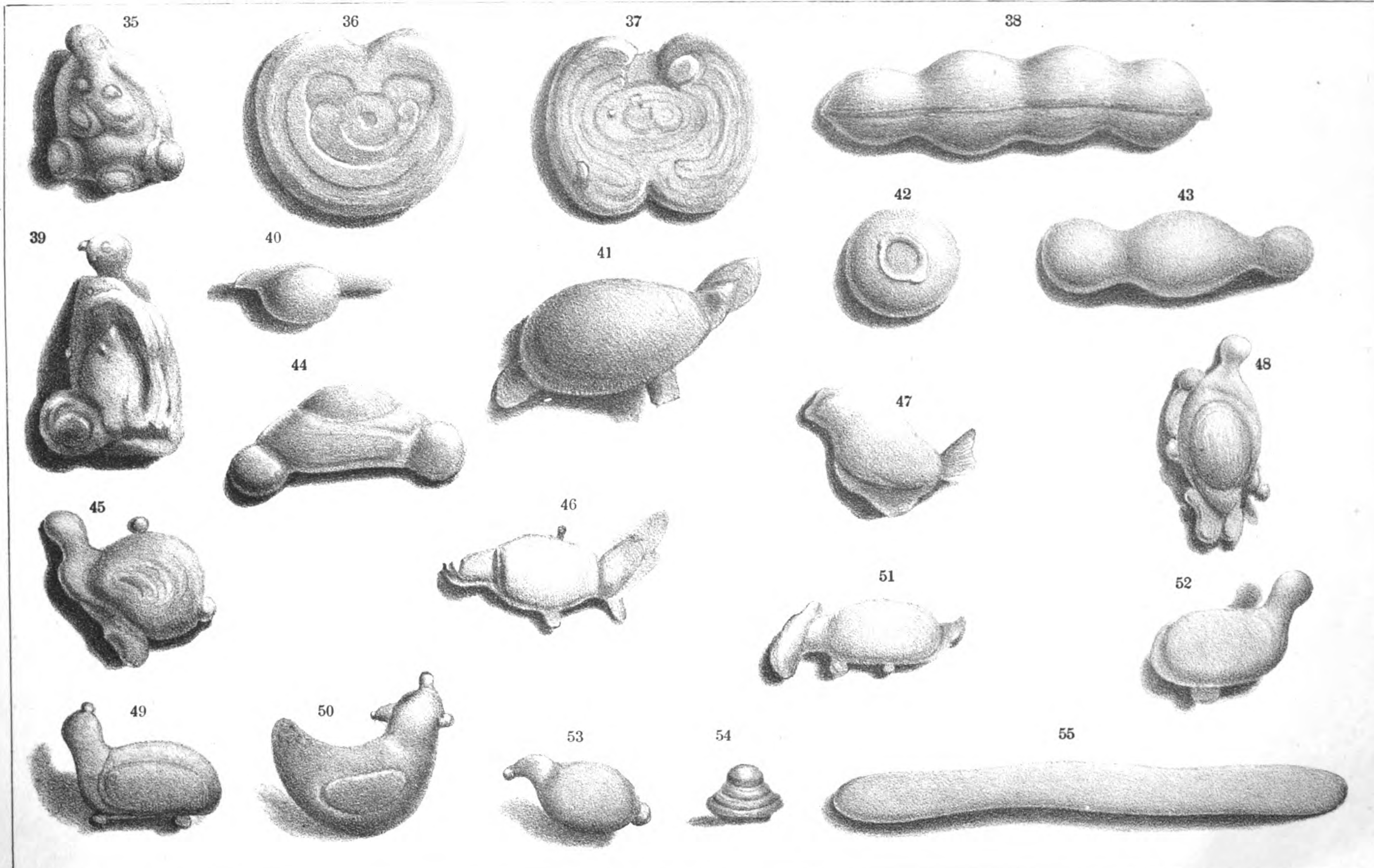
CLAY STONES.

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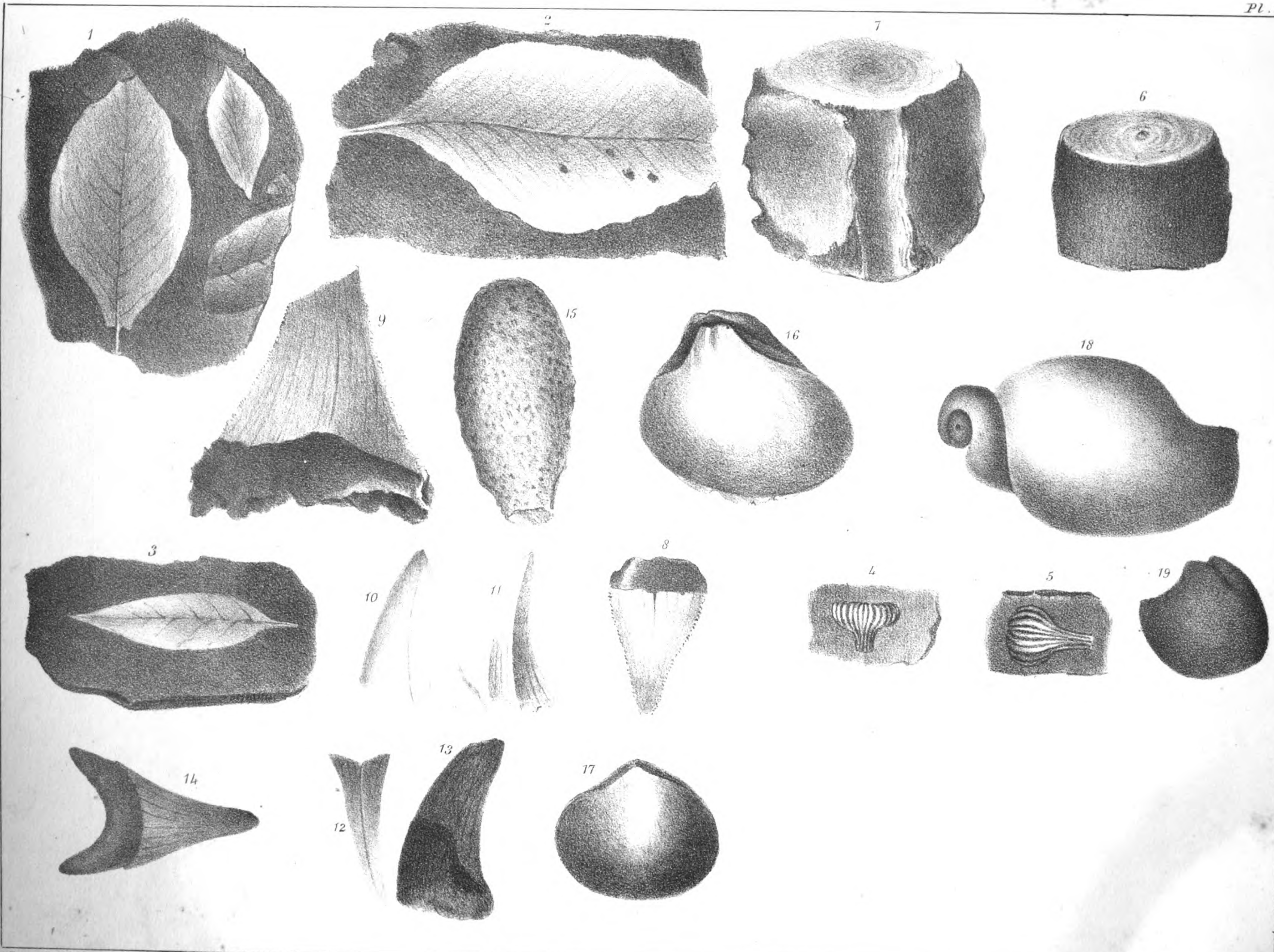
Thayer's lith. Boston.

CLAY STONES.


J. Peckham del.

B. W. Thayer's Lith. Boston

CONCRETIONS.

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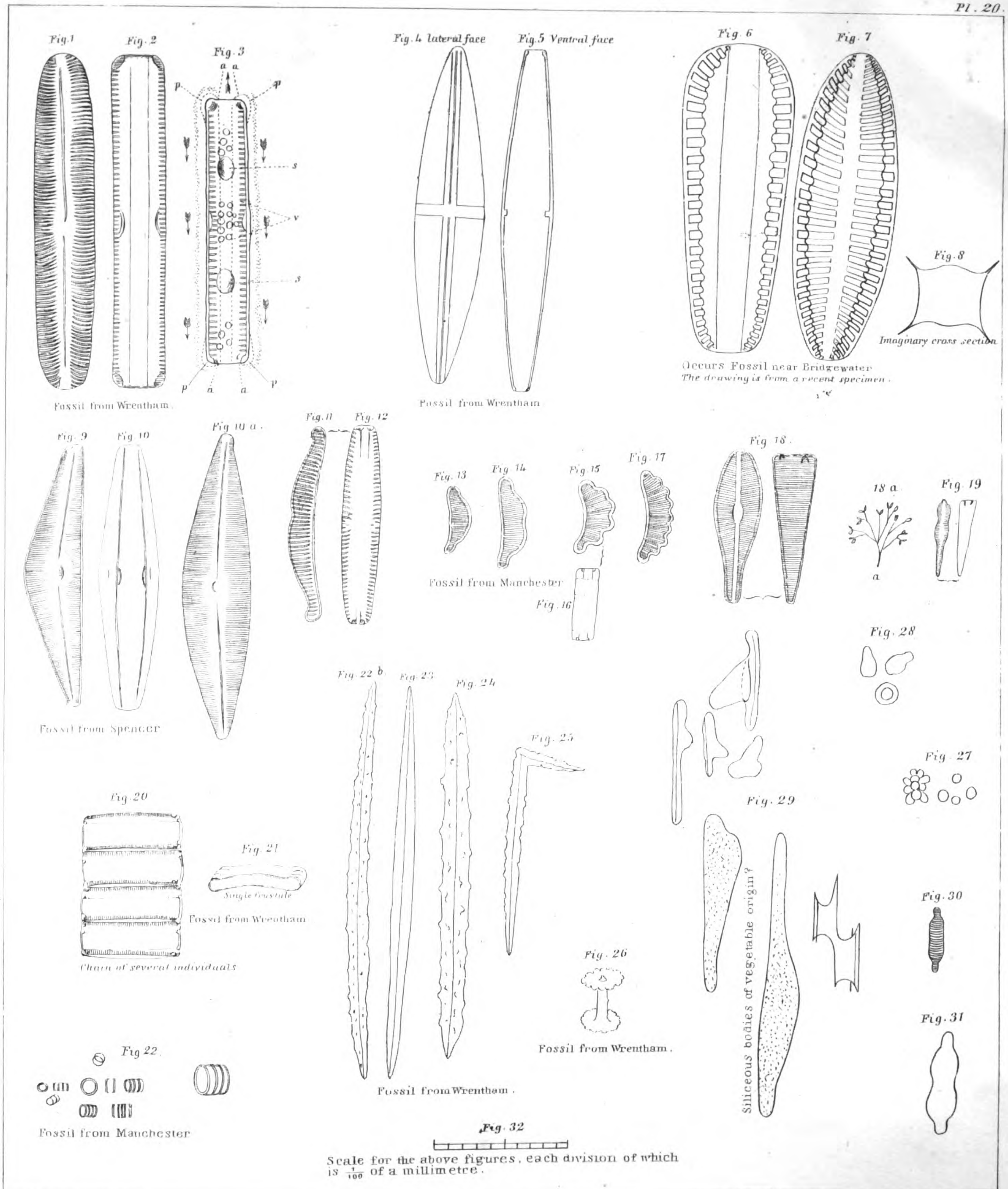
Thayer's Lith. Boston.

FOSSILS OF THE EOCENE TERTIARY.




Prof. Bailey del. B. W. Thayer's Lith. Boston.

FOSSIL INFUSORIA.

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2

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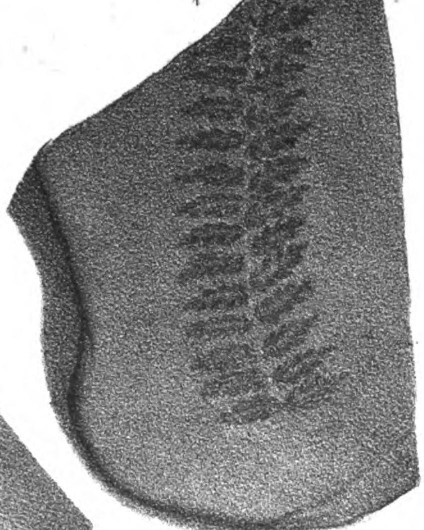
FOSSIL VEGETABLES FROM MANSFIELD.

4



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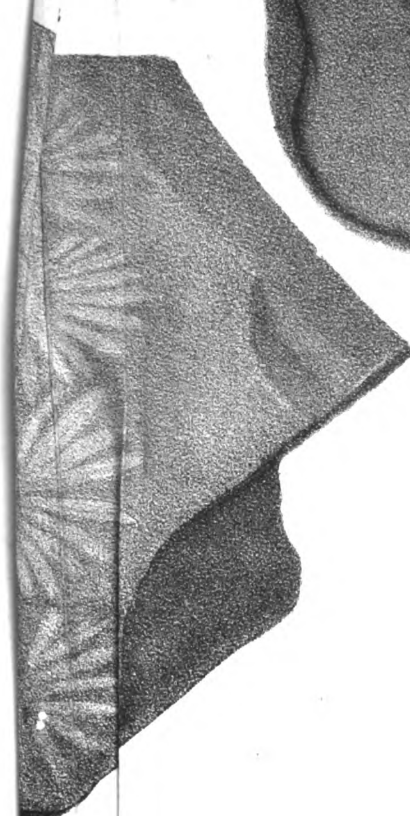

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FOSSIL VEGETABLES FROM MANSFIELD.

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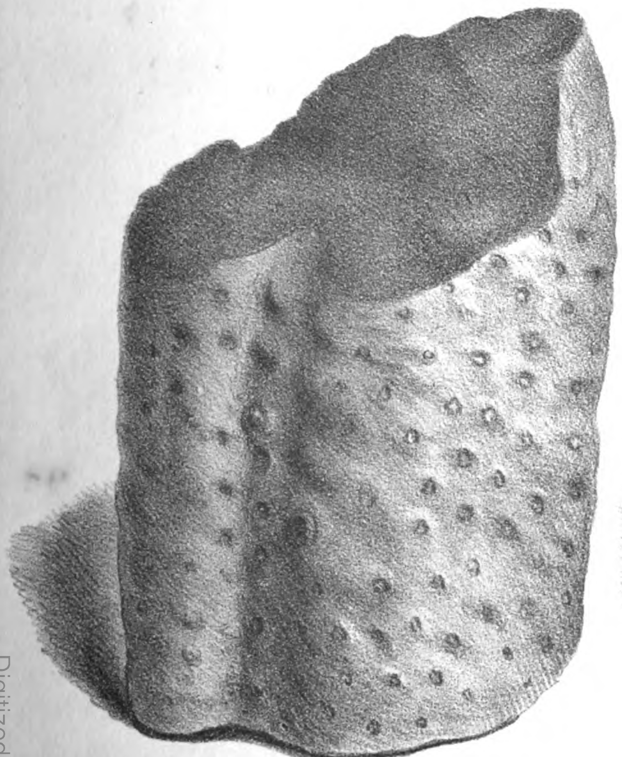

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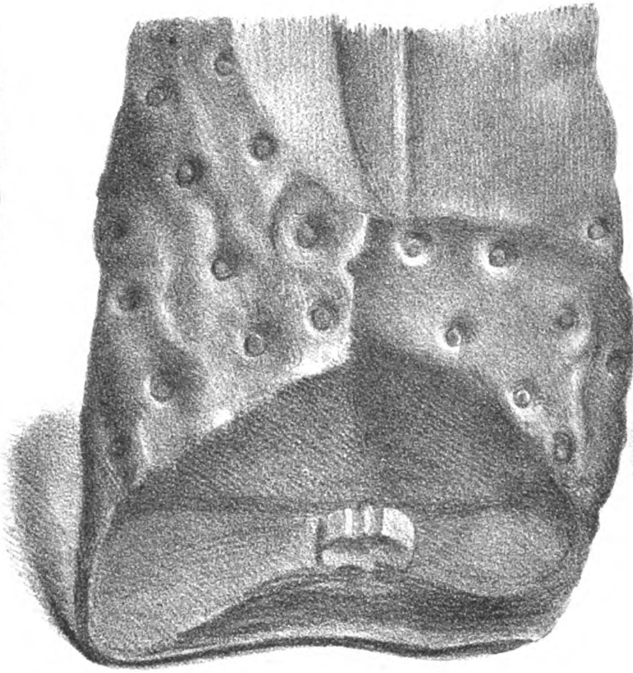

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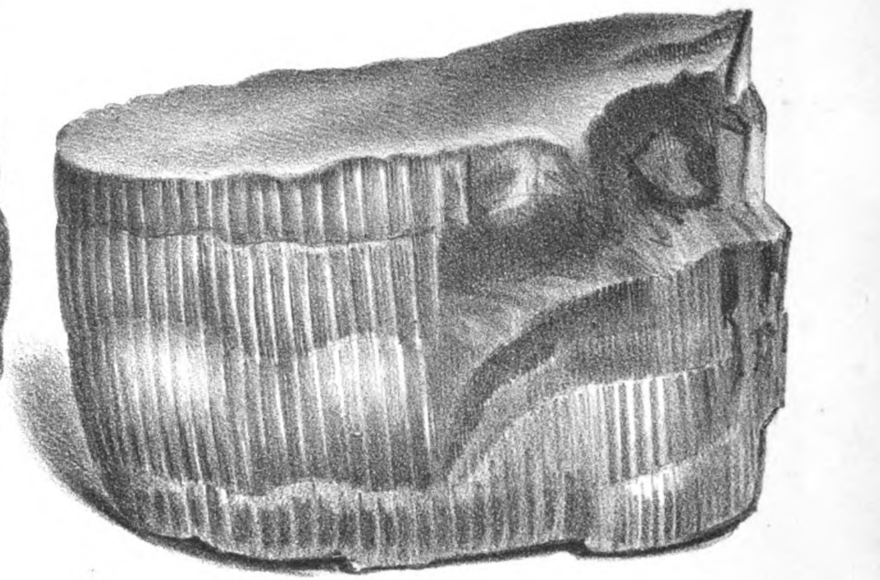

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FOSSIL VEGETABLES FROM MANSFIELD.

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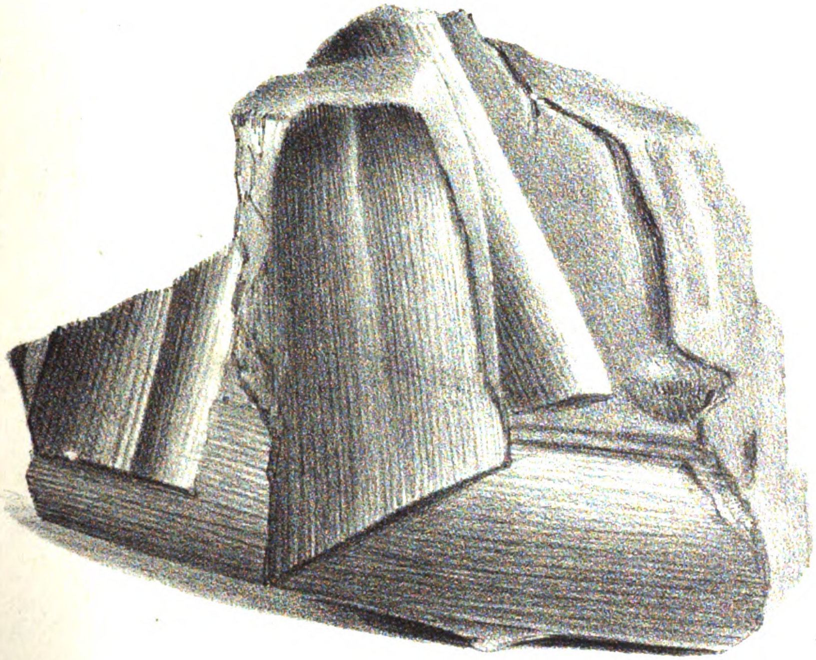

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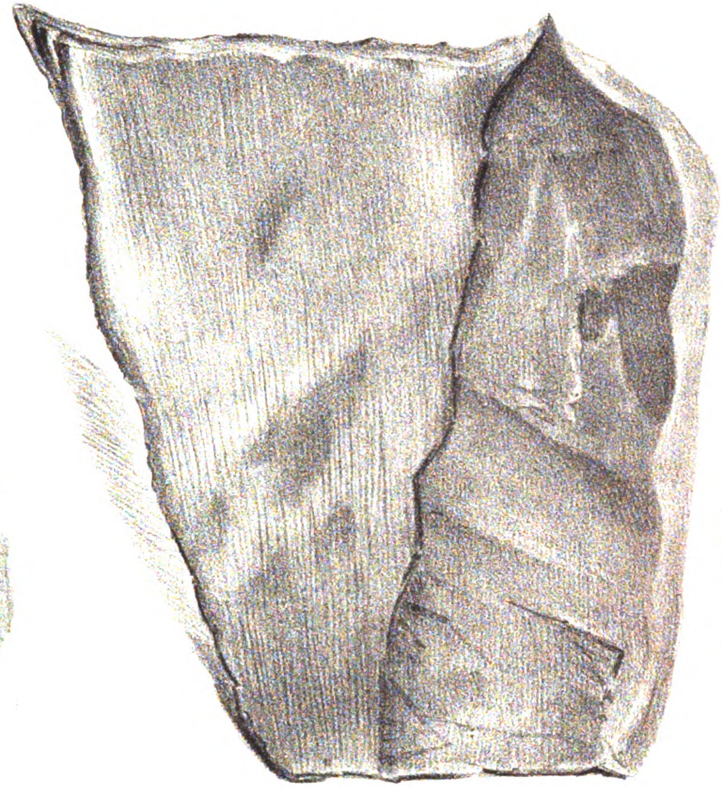

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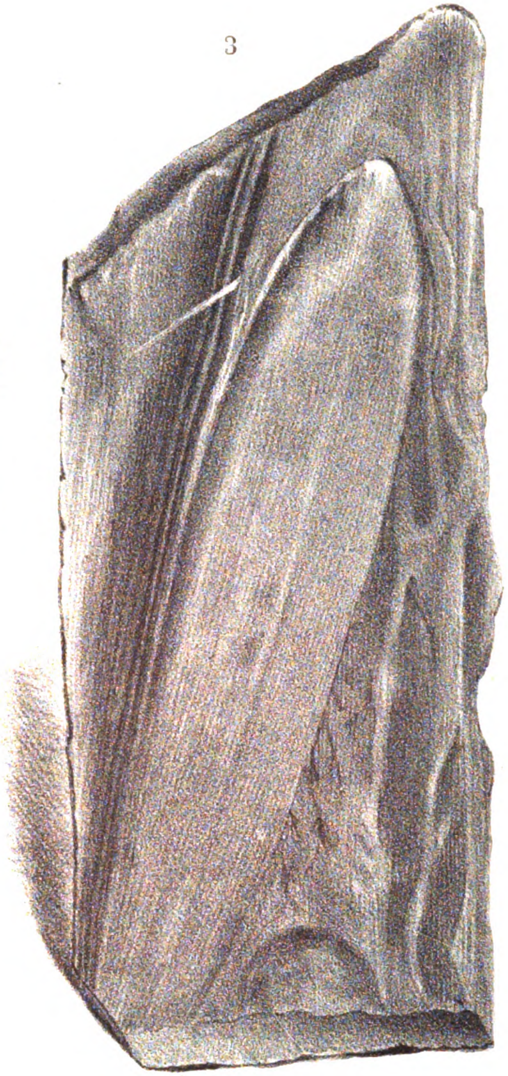

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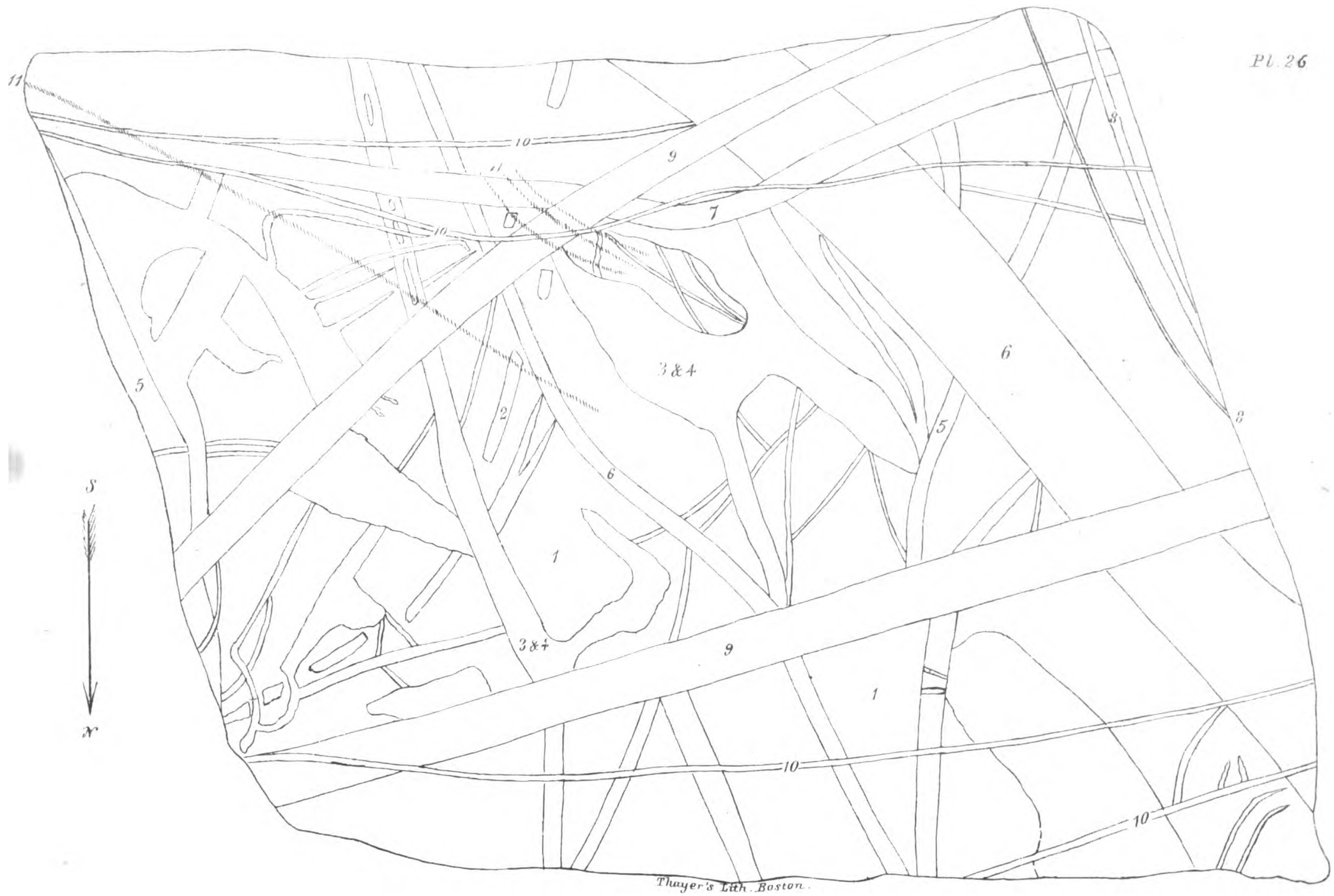
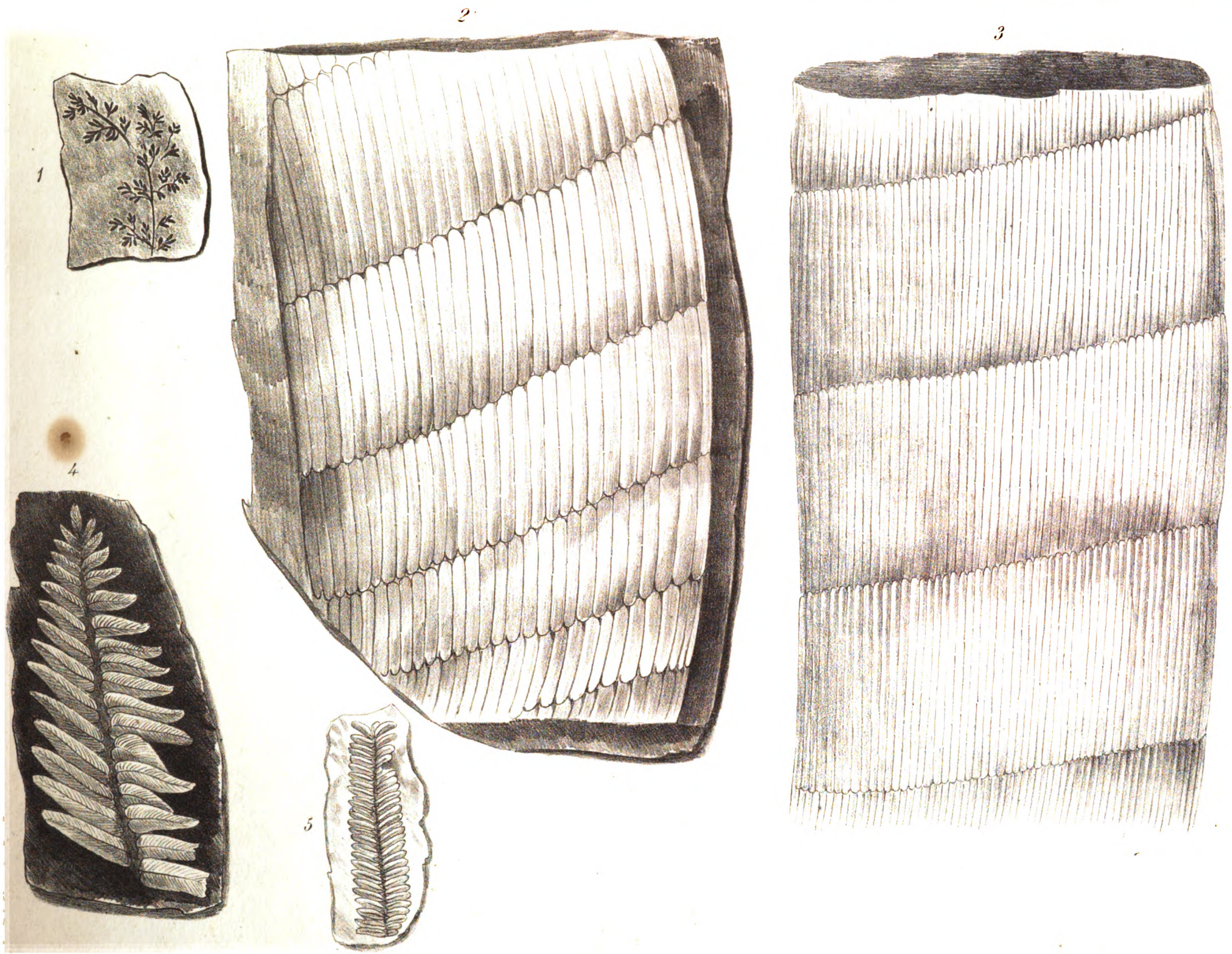
FOSSIL VEGETABLES FROM MANSFIELD.

Pl. 26



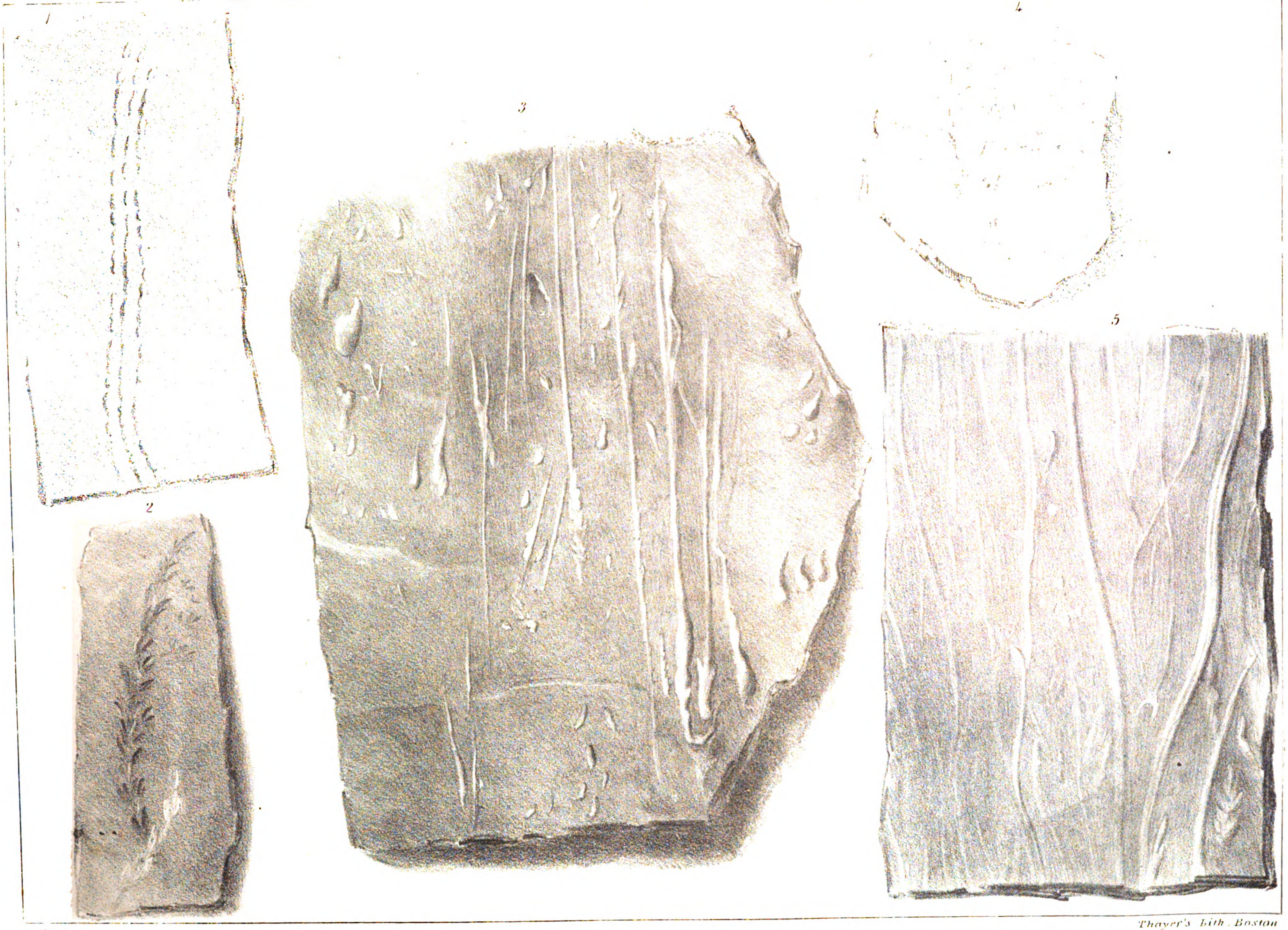

SKETCH OF VEINS IN SIENITE, SALEM.




Mrs. Hitchcock del.

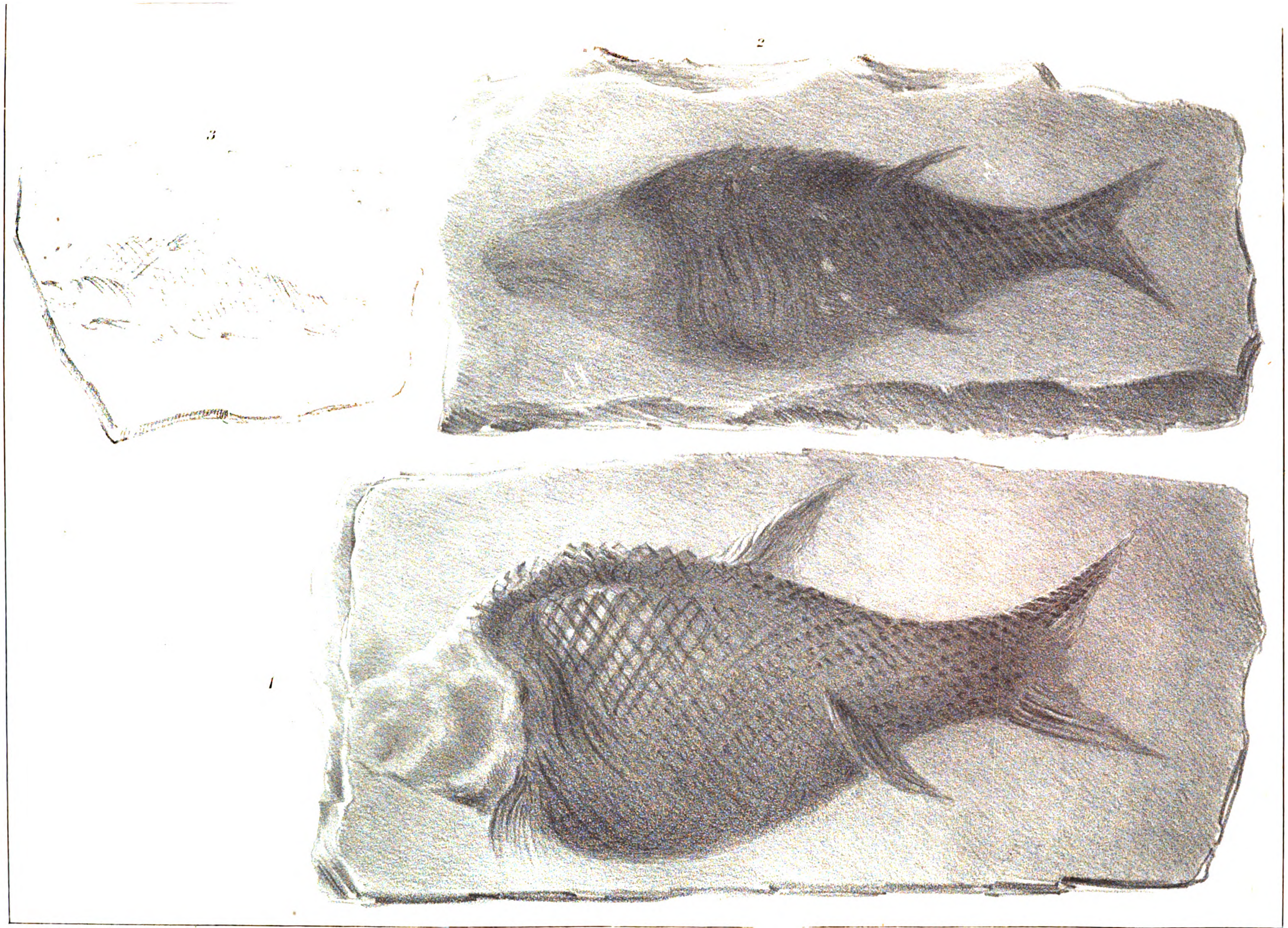
B. W. Thayer's Lithog.y Boston.

FOSSIL VEGETABLES FROM WRENTHAM.




Thayer's Lith. Boston

FOSSIL PLANTS OF THE NEW RED SANDSTONE.

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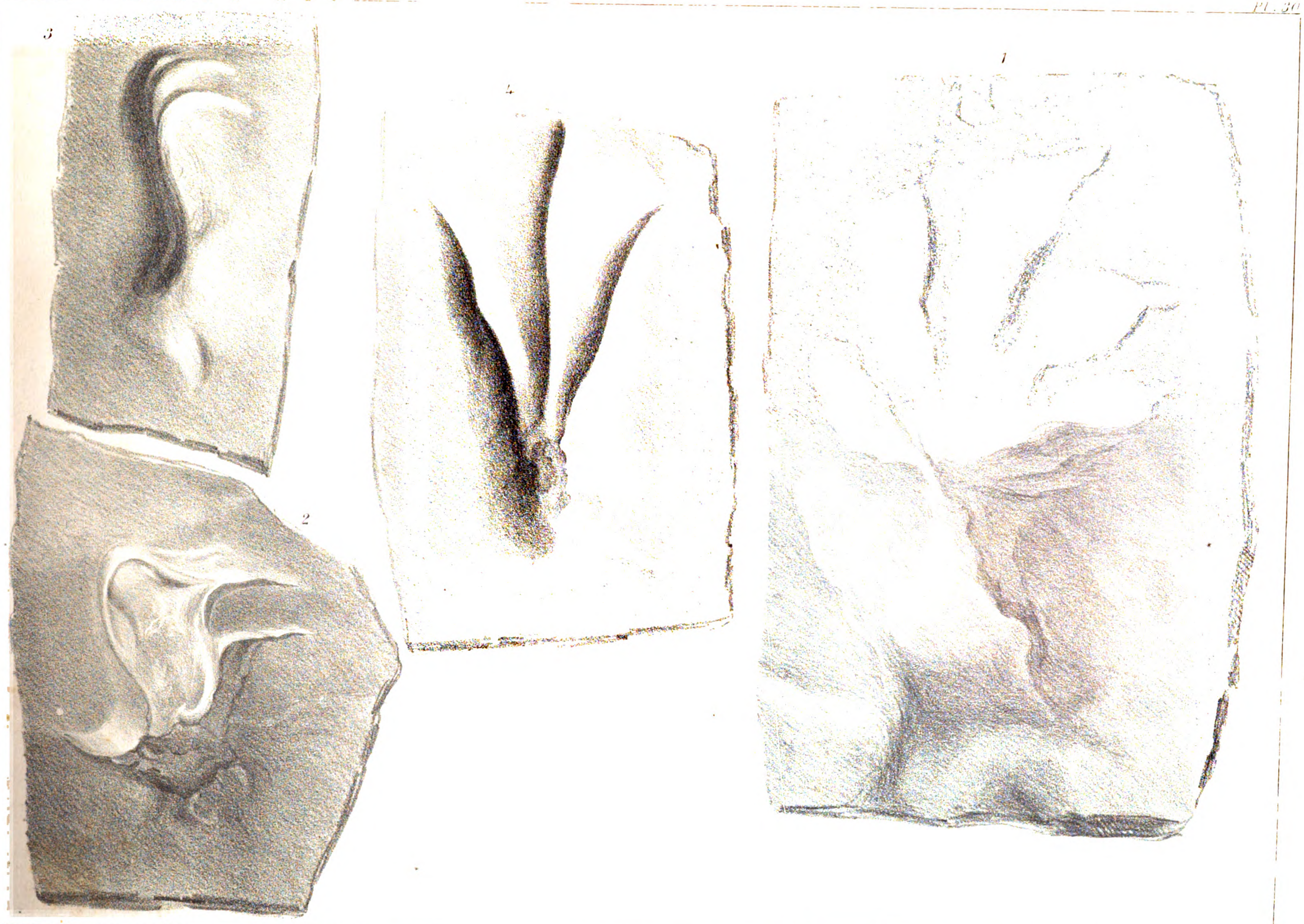
B. W. Thayer's Lithog.y

FOSSIL FISH, SUNDERLAND.



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FOSSIL FOOTMARKS.

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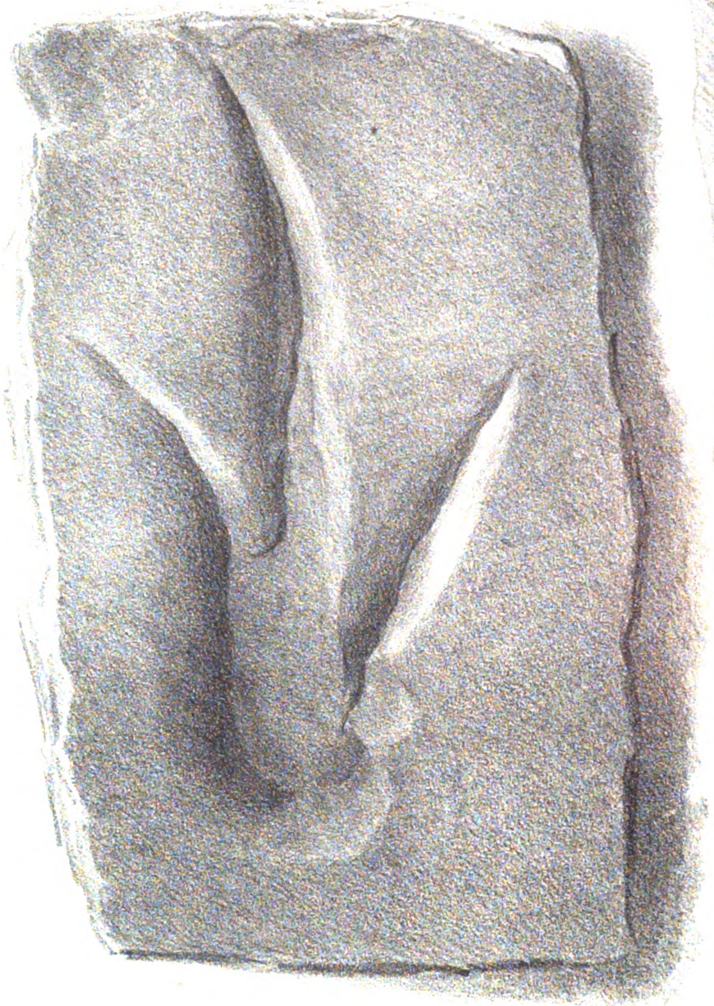

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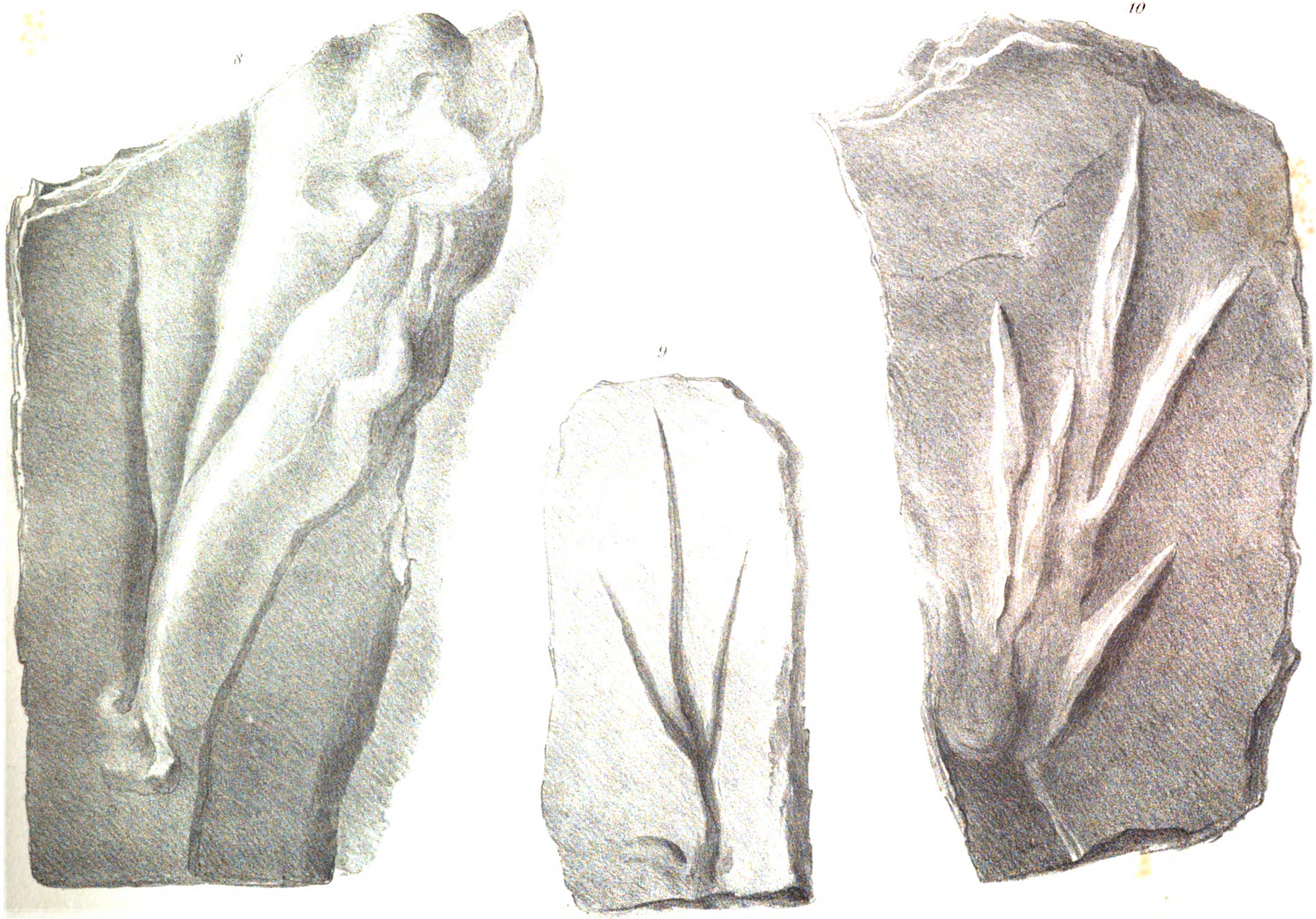


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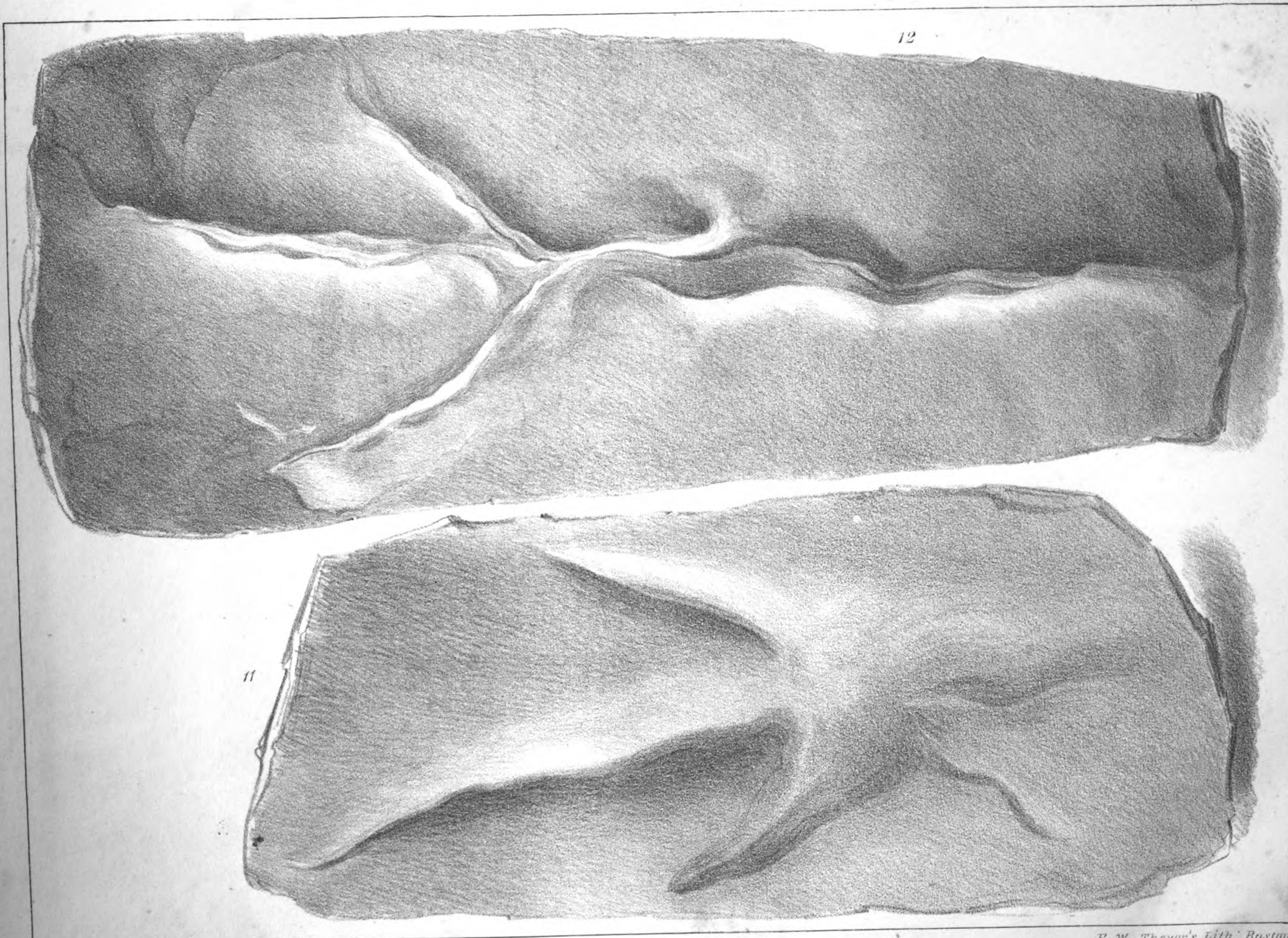


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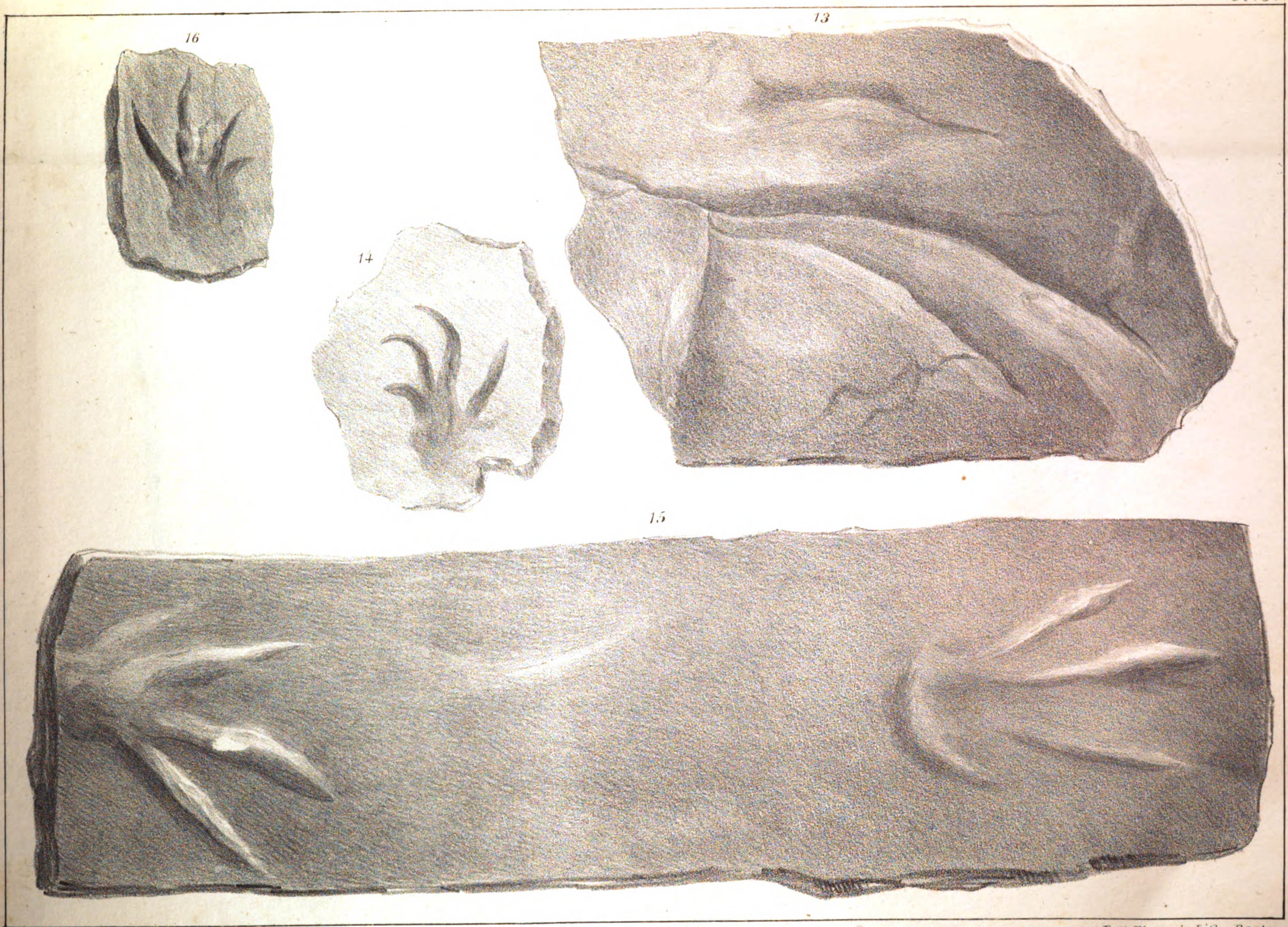


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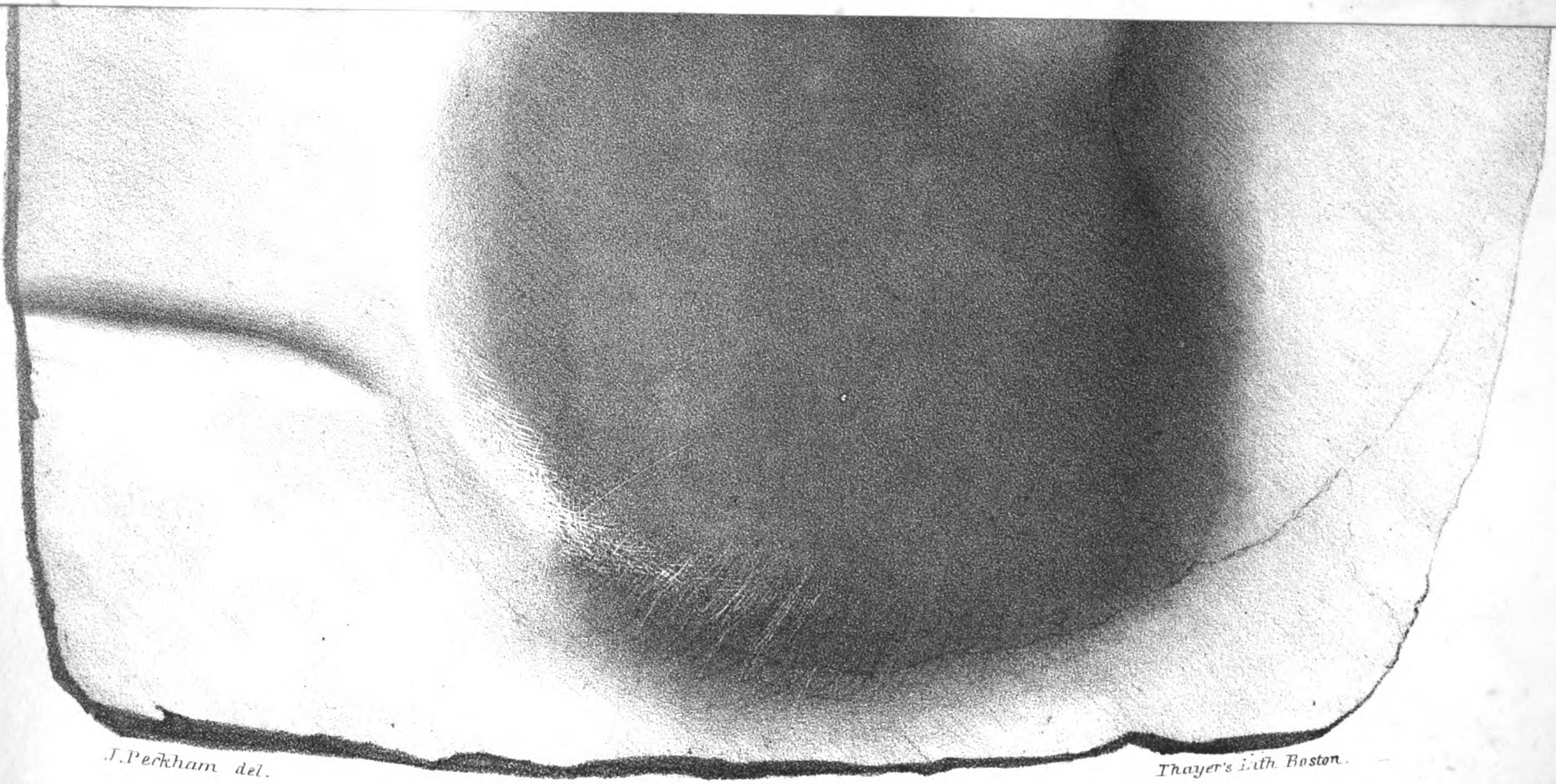

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SAUROID FOOTMARK.

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FOSSIL FOOTMARKS.

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FOSSIL FOOTMARKS.

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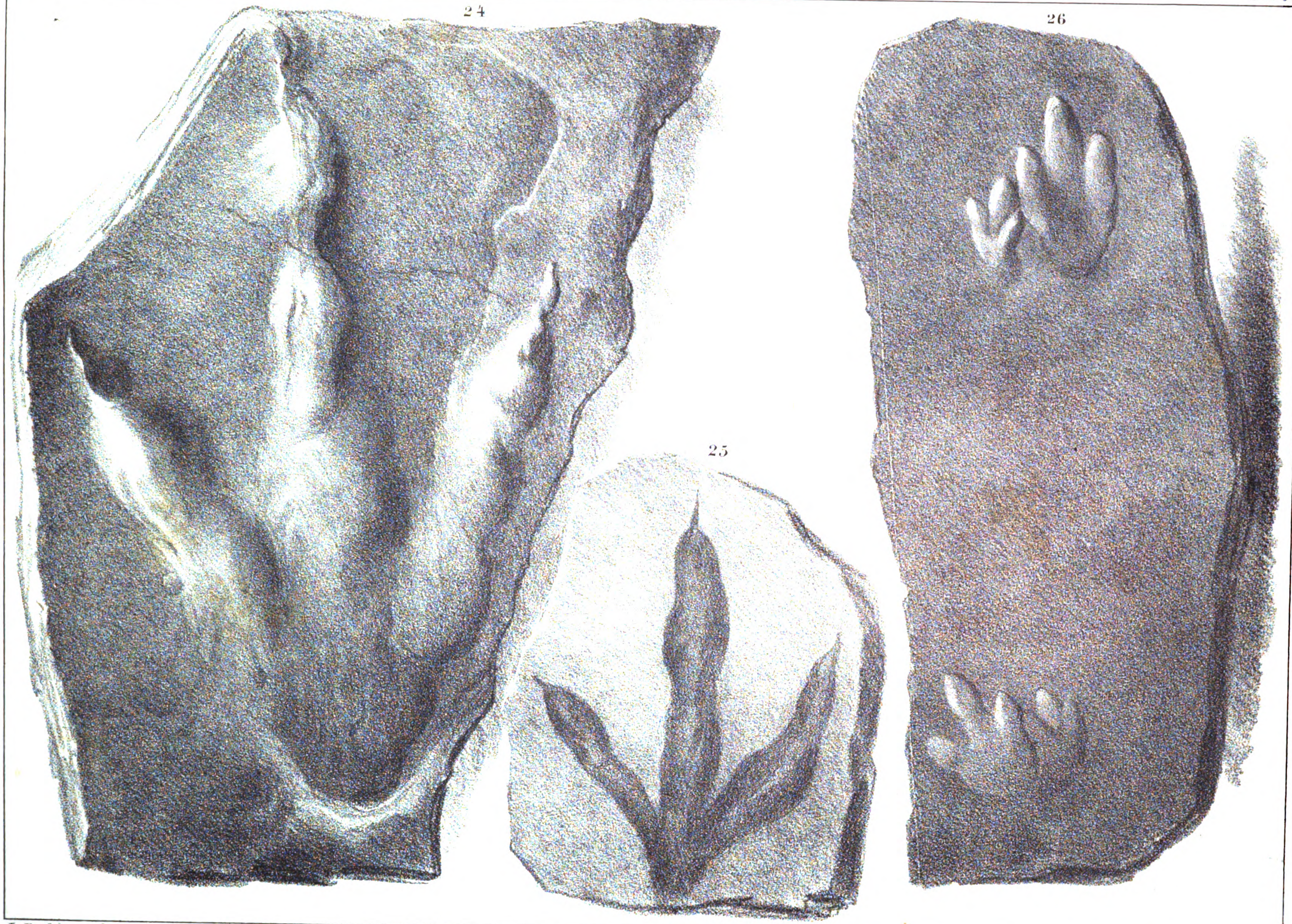

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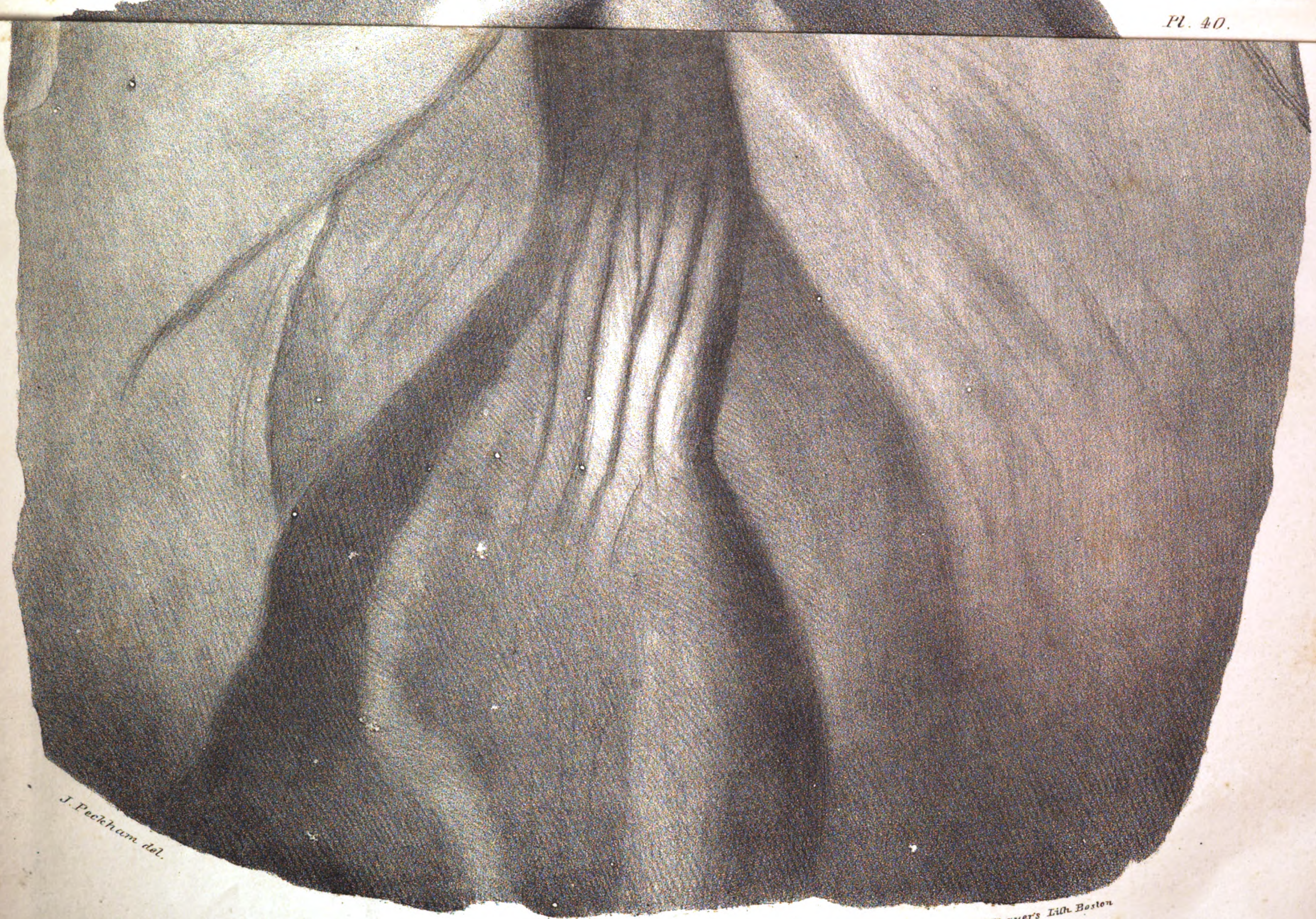

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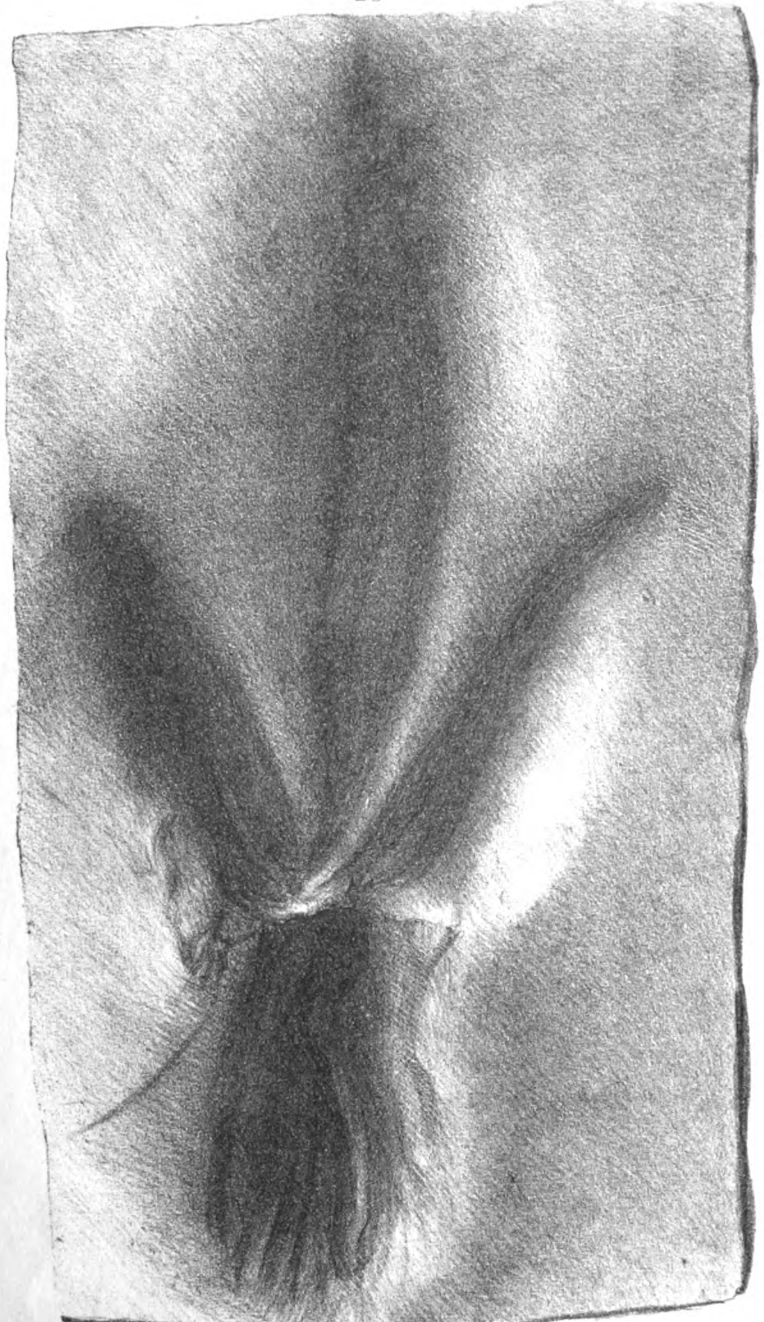

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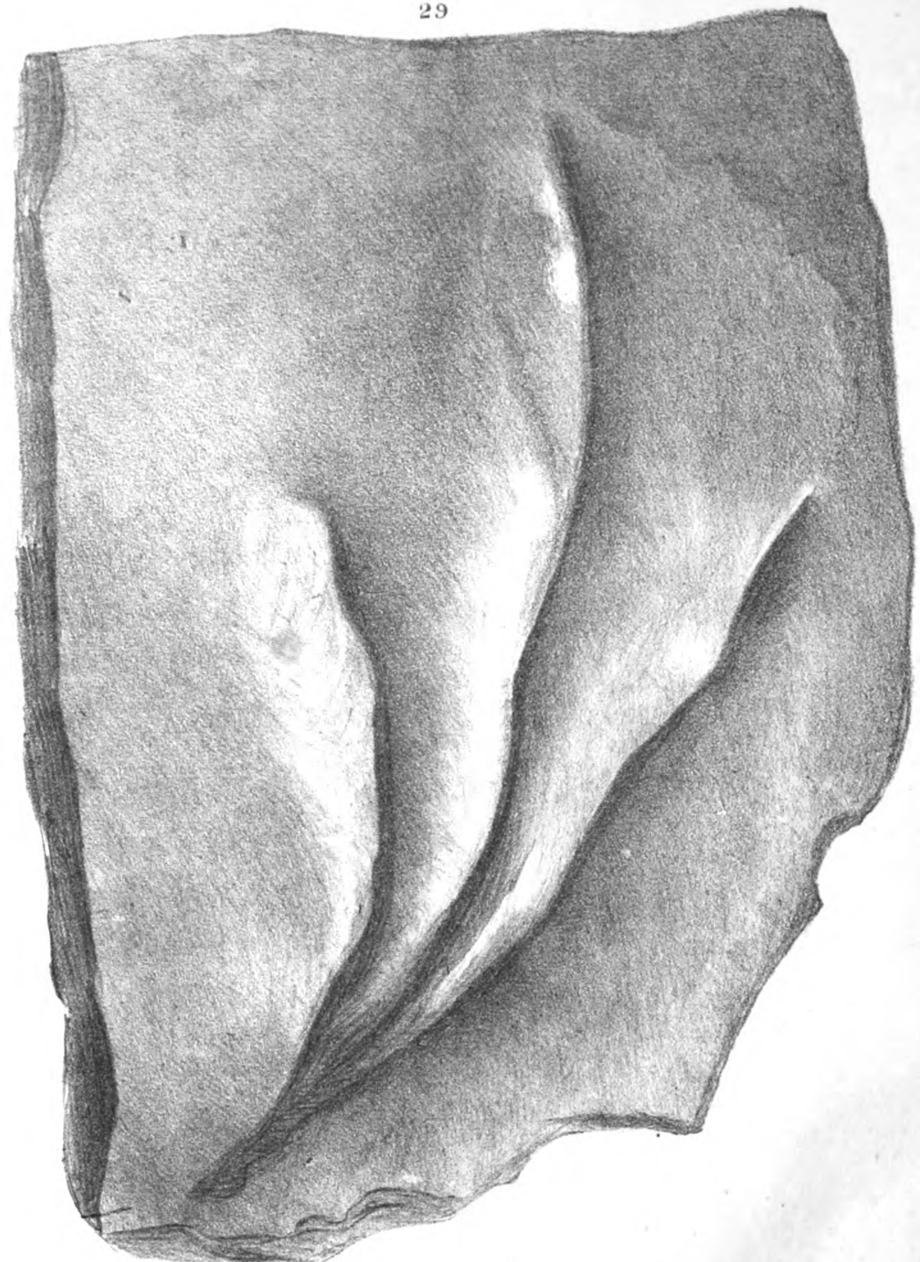

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Thayer's Lithog. Boston.

FOSSIL FOOTMARKS.

Pl. 42.

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Thayer's Lithog. Boston

FOSSIL FOOTPRINTS.

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FOSSIL FOOTMARKS.

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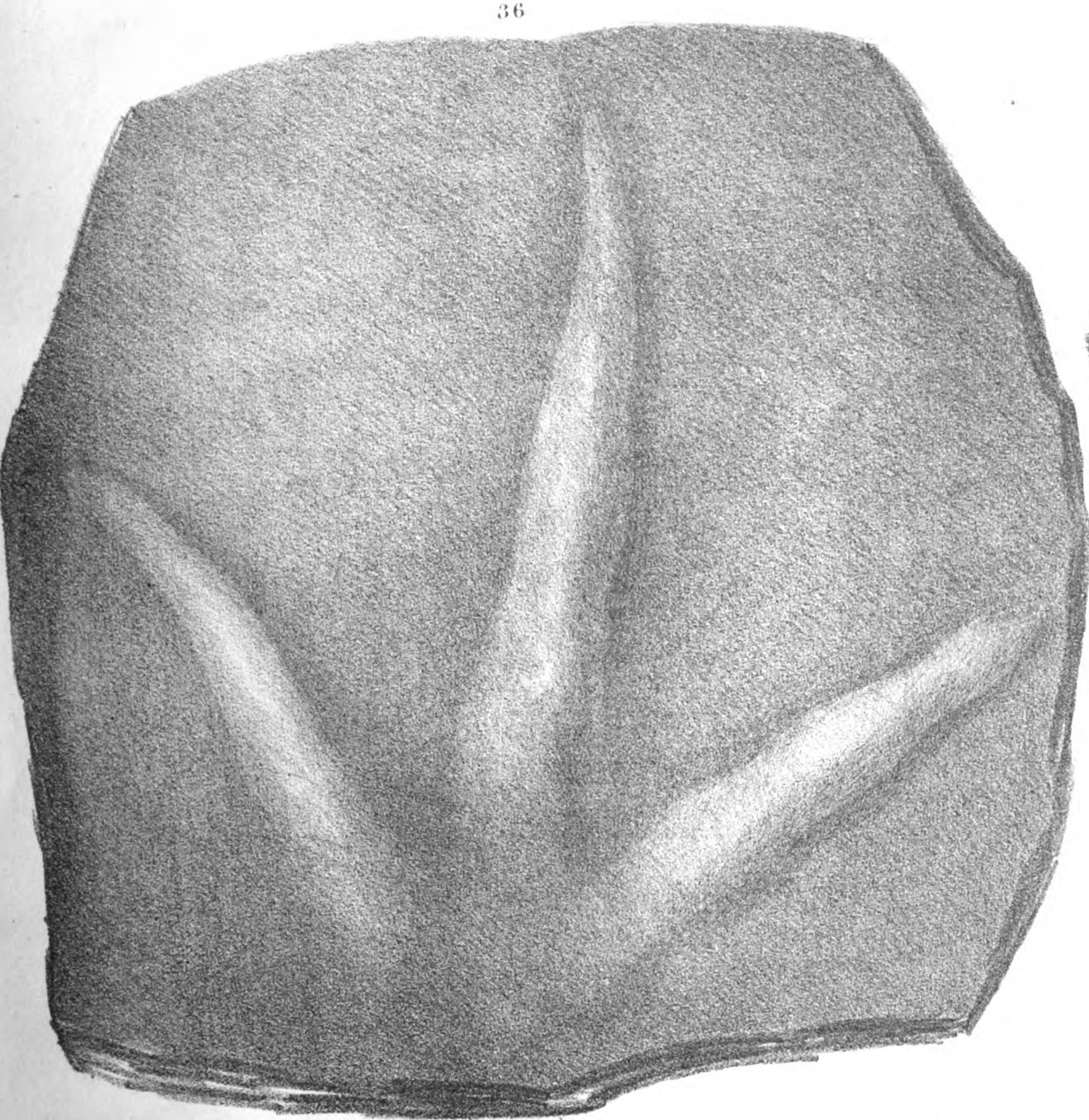

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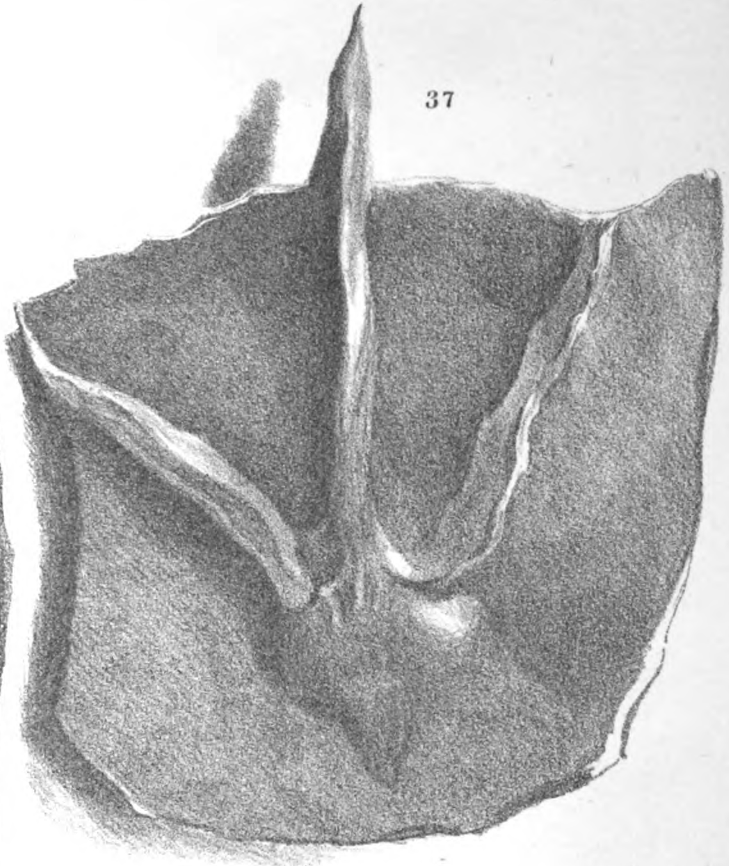

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FOSSIL FOOTMARKS.

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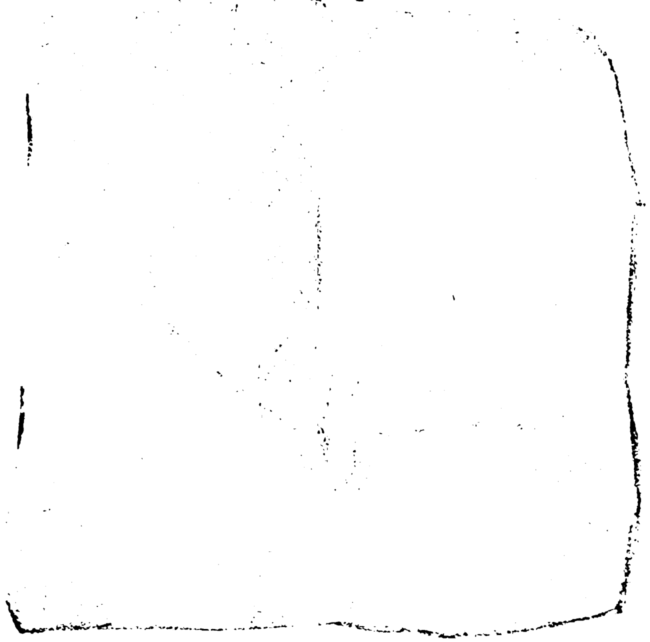

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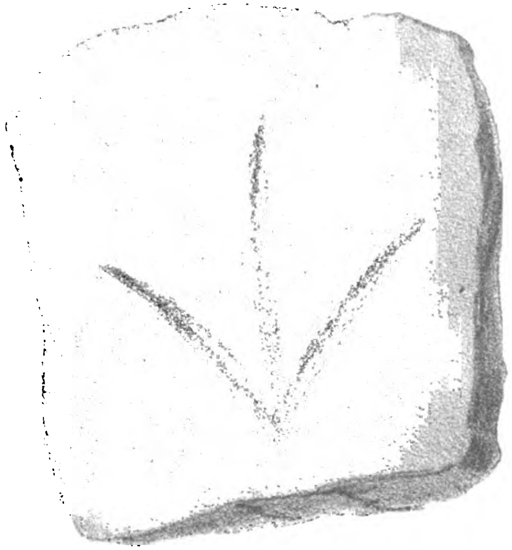

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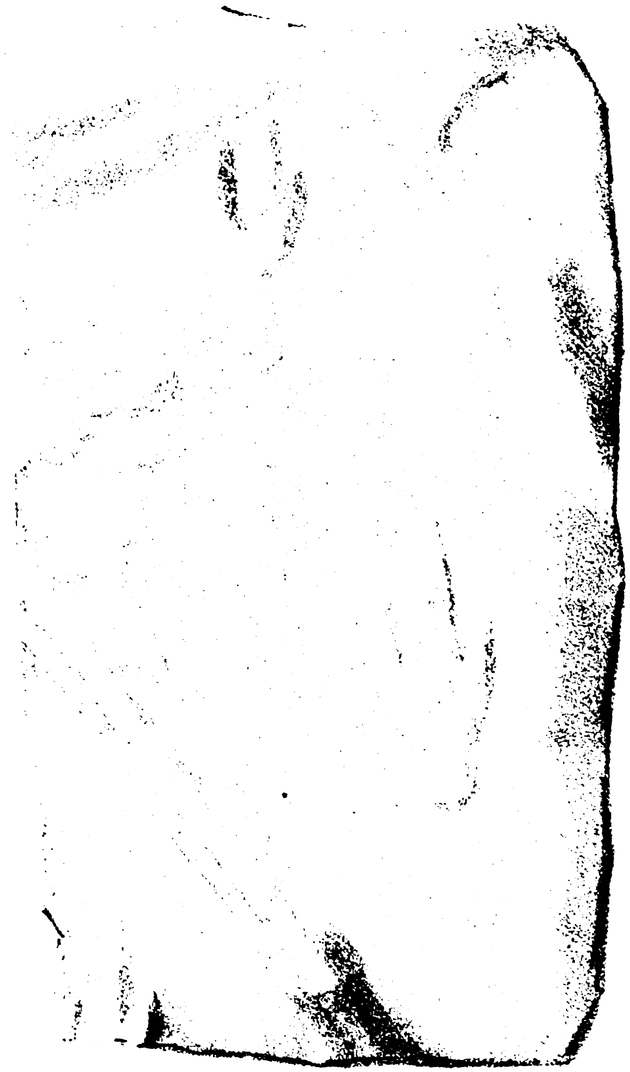

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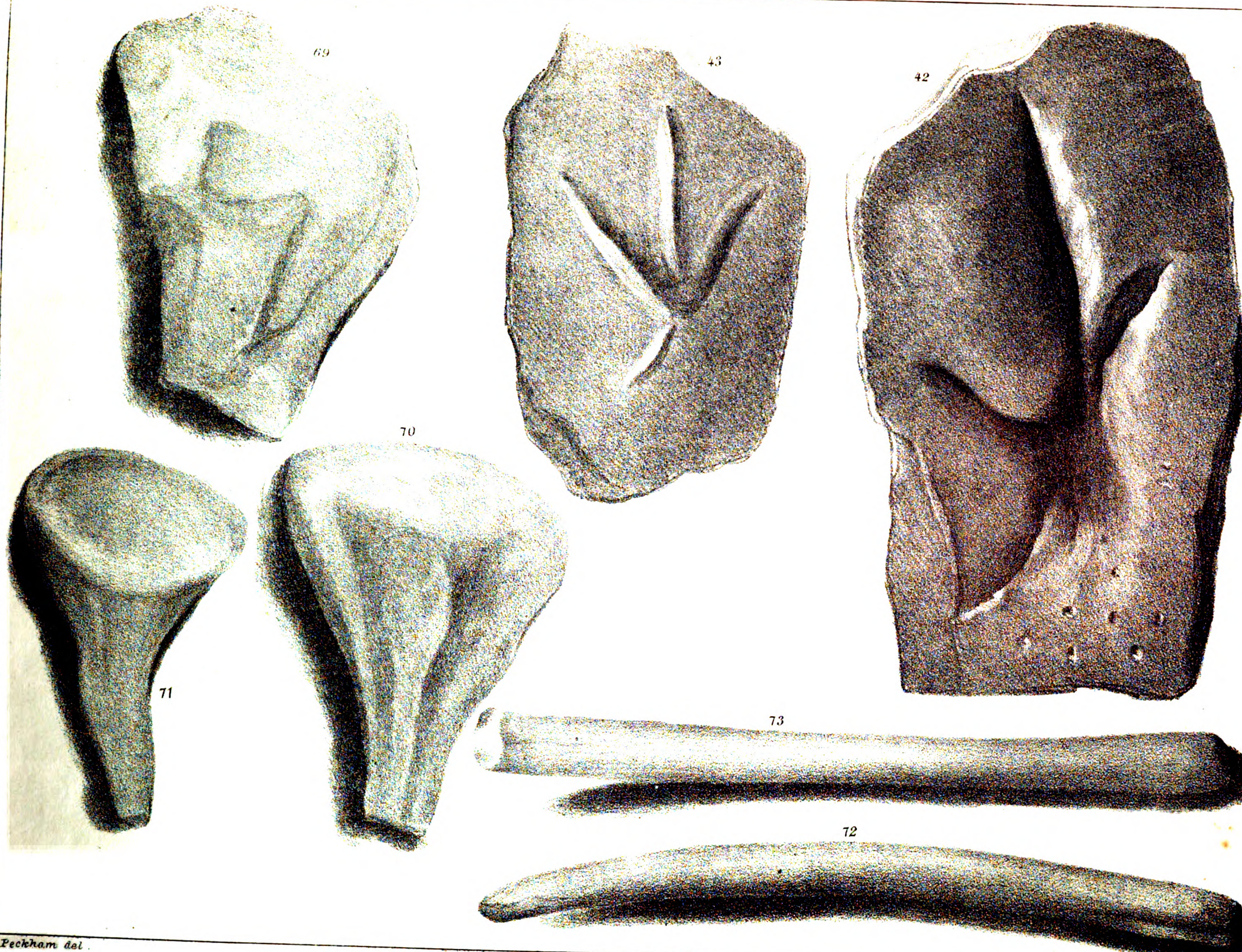


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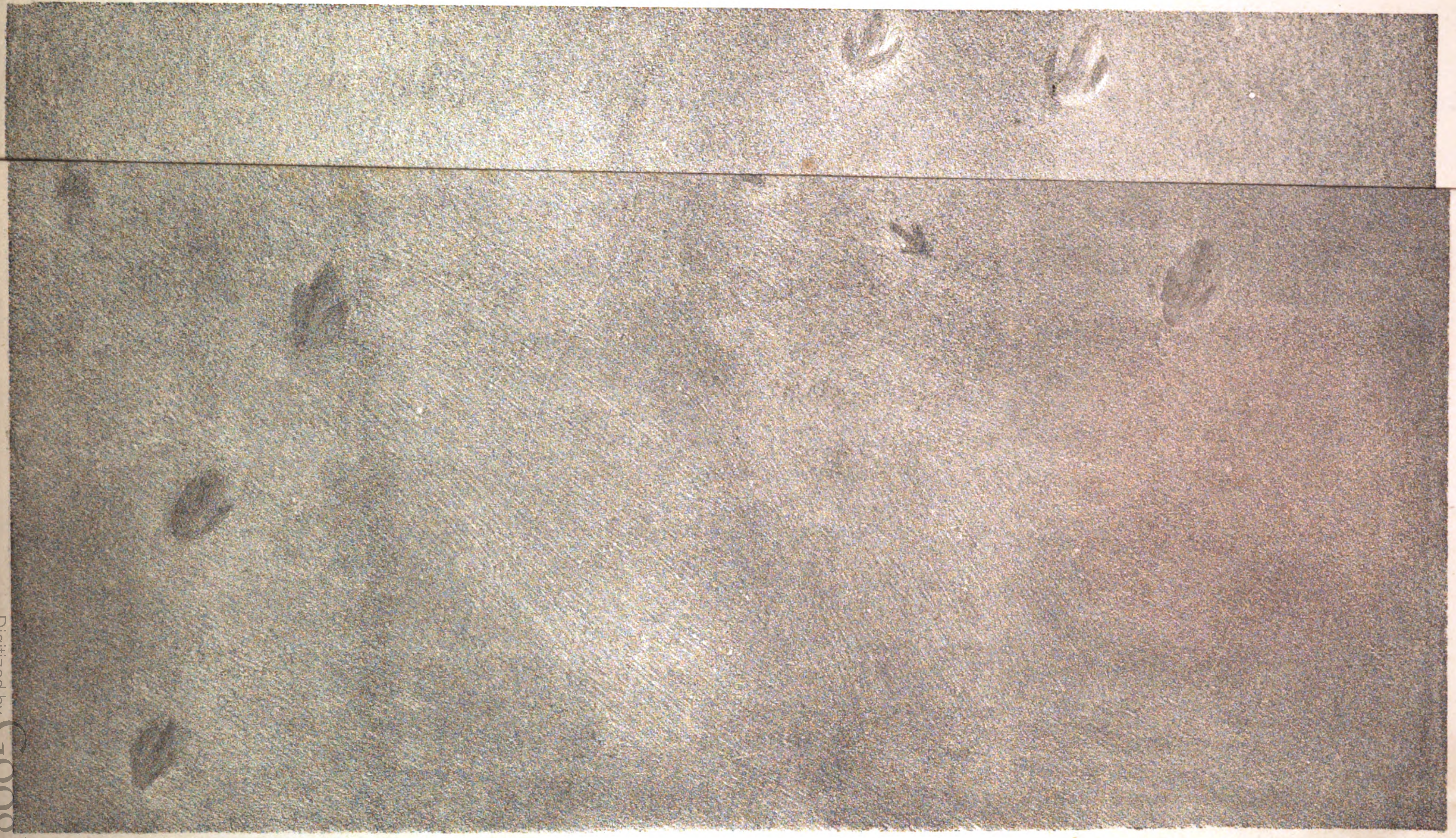
Thayer's Lithography, Boston.

FOSSIL FOOTMARKS AND BONES.

Pl. 47.



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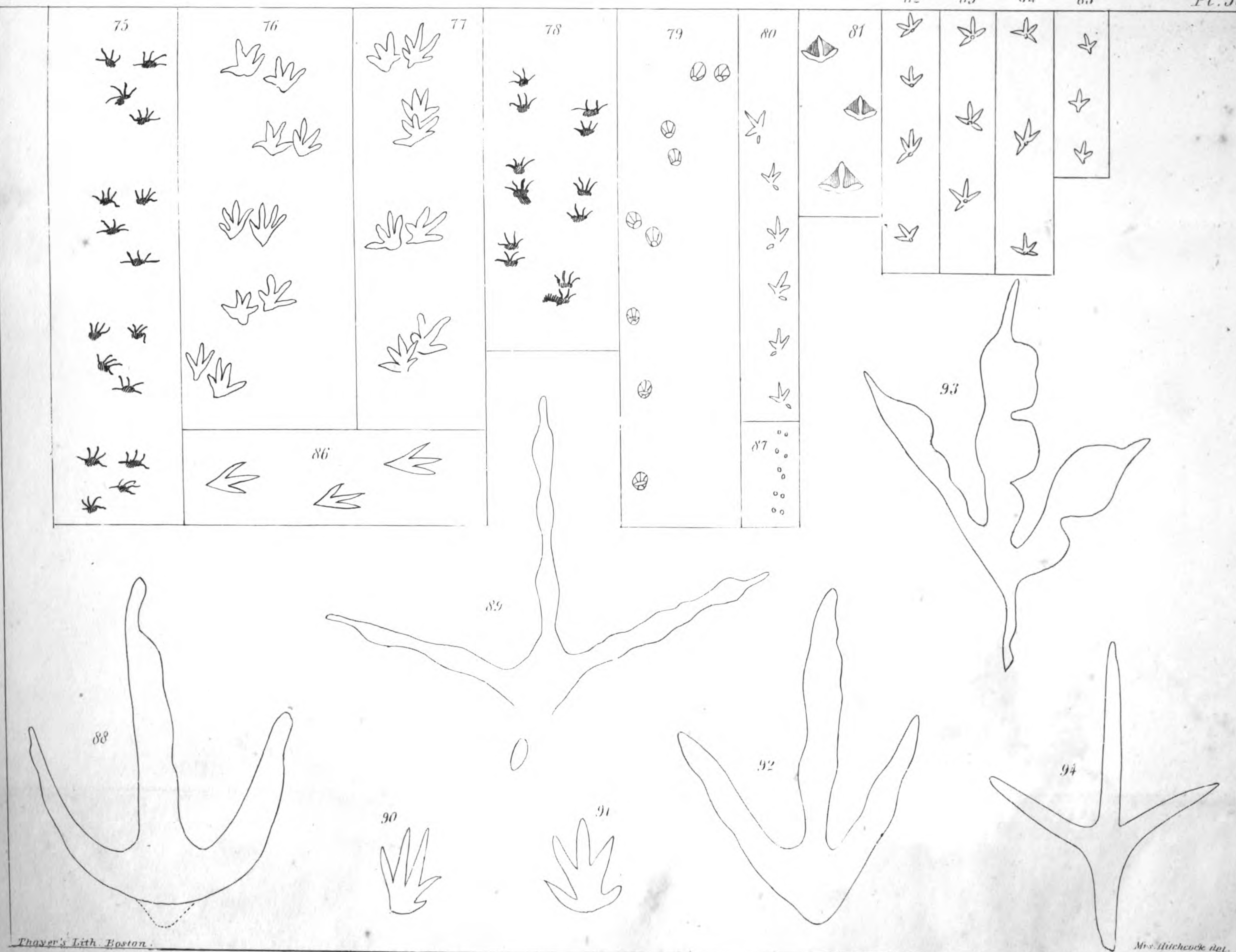
FOSSIL FOOTMARKS.




Tracks of living animals.


Mrs. Hitchcock del. Thayer's Lith. Boston

Feet and Tracks of Living Animals

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